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Hunting for Dollars

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Abstract

Using novel granular data on the global flows of wholesale and synthetic dollar funding, we show that constrained non-US banks substitute dollar borrowing from US repo markets with foreign exchange (FX) swaps at the quarter-end. As wholesale borrowing is encumbered by shadow costs, non-US banks satisfy their inelastic dollar demand by obtaining synthetic funding, for which they are willing to pay a heightened cross-currency basis. Eurozone banks in particular hunt for dollars by engaging in such repo-FX swap substitution, with the benefits largely accruing to US dealers. Our study explains the increase in synthetic dollar borrowing and deviations from covered interest rate parity (CIP) observed at the quarter-end and uncovers how global banks manage short-term dollar liquidity across multiple money markets.

Keywords: US Dollar, Global Banks, FX Swaps, Repos, Intermediary Constraints, Covered Interest Parity, Regulation.

JEL classification: F31, G12, G15

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1. Introduction

As the world's reserve currency, the US dollar is essential not only to the operations of financial institutions around the world, but also to the global real economy. Its reliable availability and seamless transmission to actors outside of the US are thus crucial for financial stability. Recent years, however, have seen frequent breakdowns of no-arbitrage principles implying a scarcity premium for dollar funding. This raises important questions: what constrains the free provision of dollar liquidity across various money markets? If the unintended consequences of banking regulation are at fault, through which precise mechanism do they impact these markets?

To address these questions, we study how financial intermediaries obtain the dollar from two major sources: US wholesale funding markets and FX swaps. We show that frictions in wholesale money markets spill over to currency markets: when constrained by financial regulation, non-US banks replace dollar funding obtained through repurchase agreements (repos) with synthetic dollar funding. We provide empirical evidence that demand for FX swaps is inelastic, and that banks, especially global Eurozone banks, are willing to incur a higher cross-currency basis for their funding, provided it remains lower than the shadow costs associated with repo borrowing. Our paper thus explains how frictions in wholesale markets contribute to pricing distortions in FX markets.

We structure our analysis in three parts. First, we map global dollar funding by analyzing novel and granular data on institutions' activity across money markets. We access a bespoke data set from Continuous Linked Settlement (CLS), classifying 4,170 banking entities and their customers by the *nationality* of their ultimate parent.[1] This approach allows us to match agents to the reporting currency of their consolidated balance sheet, which is more indicative of their regulatory framework and deposit base than their geographic location, which is often concentrated in major financial centers such as London.[2] We then pair this new dataset with bank-level observations from US and European repo markets. Mapping the global FX swap market network reveals that both US and non-US G-SIBs provide dollar funding to their customers. Crucially, however,

[1] For example, an FX swap traded by J.P. Morgan in London identifies the party as a US global systemically important bank (G-SIB).

[2] We sort market participants into six regions: the US, the Eurozone, the UK, Switzerland, Japan, and a residual group combining all other nationalities (ROW). We further observe non-banks in CLS, allowing us to distinguish between G-SIBs, regular banks, and non-banks, resulting in 18 different agent types.

US G-SIBs provide dollar funding to non-US G-SIBs, and thus are an important provider of dollar liquidity, even to other dealer-banks.

Second, we hypothesize that the Basel III regulatory framework incentivizes constrained non-US banks to substitute dollar funding from US repos with FX swaps. These two instruments can serve the same economic function of obtaining dollar liquidity, but have very different outcomes for a bank's leverage ratio (LR). As a risk-unweighted capital adequacy measure, the LR imposes constraints and opportunity costs on banks' balance sheet space. While dollar funding via repos expands the balance sheet and worsens the LR, FX swaps are off-balance sheet instruments, and thus only 1% of their positions count towards the LR calculation. We identify this substitution effect by leveraging another artefact of Basel III regulation. Most jurisdictions around the world mandate that banks report their regulatory ratios as they stand at the end of the quarter, thus incentivizing certain banks, especially the Eurozone, to 'window-dress' their quarter-end financials and present a safer financial picture to regulators than appropriate. The resulting effect is that on reporting dates, Eurozone banks dramatically decrease their USD repo borrowing and correspondingly increase synthetic funding, with the economic magnitude of this substitution at around 50 billion dollars. Banks in the UK and US, however, calculate their LRs using an average of daily values throughout the quarter. We therefore identify the motivation for substitution through a difference-in-differences analysis demonstrating that only those banks with a regulatory incentive perform this practice.

Finally, we address the question of whether the substitutability of wholesale and synthetic dollar funding documented in our study has pricing implications. To do this, we provide a simple analytical framework connecting the regulatory costs of US dollar funding to the covered interest rate parity (CIP) principle; this shows that for a bank to be indifferent as to its funding source, the price of synthetic dollar borrowing (via FX swaps) must equal the effective cost of its outside option, i.e. short-term funding in US wholesale money markets. In our setting, regulatory constraints and the need to source collateral can be seen as shadow costs imposed on top of interest rates. Consequently, the market-wide cross-currency basis will adjust to reflect the increase in shadow costs associated with borrowing US dollars (relative to domestic currency). Quarter-end spikes in the cross-currency basis reflect that regulation disproportionately penalizes secured USD borrowing in US wholesale money markets. Constrained banks are then willing to pay a higher cross-currency basis, as long as it is less than the increased shadow cost of borrowing in US money markets. For Eurozone banks, the shadow costs associated with secured borrowing outpace the premium on synthetic US dollar funding, prompting them to raise US dollars through the latter at quarter-end. The cross-currency basis can also be evaluated through the lens of the Funding Valuation Adjustments (FVA) associated with synthetic dollar funding, which embed smaller shadow costs than an equivalent position in US money markets (Andersen, Duffie, and Song, 2019). The large shadow costs of wholesale dollar funding represent severe intermediation frictions as described in Gabaix and Maggiori (2015).

We empirically validate our framework's implication that non-US banks' possess inelastic demand for the dollar. We use a granular instrumental variables (GIV) approach (Gabaix and Koijen, 2024) to confirm our hypothesis: a 1% increase in the basis results in a 0.54% reduction in demand. Our results further suggest that demand shocks to non-US institutions impact the cross-currency basis, and we observe a correlation between shocks to banks' wholesale funding and the basis. Furthermore, to shed light on the dollar's borrowing costs (and the profits earned from supplying it), we obtain data on settled FX swap trades, showing us the swap points actually paid by various institutions and nationalities. Overall, non-bank customers are the single largest payers of the cross-currency basis, while G-SIB banks profit by being on the other side of such trades providing USD liquidity. Among globally active dealers, US G-SIBs earn the highest basis net income, consistent with their relative ease in supplying US dollar funding. At the quarter-end, the effective cost of obtaining the US dollar via FX swaps increases for all market participants. According to our estimates, non-US G-SIB banks incur large *additional* basis payments of up to 4.7 billion of USD per year for dollar purchases due to the quarter-end turn, although we show that most of the cost is ultimately passed-on to end-customers such as non-banks. In addition, constrained non-US banks are willing to incur additional basis payments to window-dress their balance sheets, but do so in a cost-efficient manner: for example, Eurozone banks pay no more than 37 million of USD per year as a result of repo-FX swap substitution. While gross basis payments for USD borrowing at quarter-end rise considerably, global banks minimize the total net losses such that their intermediation business over all G7 currencies and tenors remains profitable. Overall, these results provide evidence supporting our hypothesis that the basis responds to (regulatory) shadow costs, which increase at quarter-ends. They further align well with the notion that obtaining dollar funding involves efficiently weighing the costs, including non-pecuniary burdens, of borrowing through wholesale and synthetic means.

While the extant literature has conclusively linked Basel III banking regulation with the breakdown of CIP (Du, Tepper, and Verdelhan (2018); Cenedese, Della Corte, and Wang (2021)), several important questions remain unresolved: if regulation penalizes balance sheet space, why is it that global FX swap positions *surge* to the tune of 200 bill. USD at the quarter-end, as demonstrated in Kloks, Mattille, and Ranaldo (2023) and further substantiated in our analysis? Why is FX swap pricing consistently distorted during such periods, when these instruments are largely exempt from the crucial LR regulation? And why is it that the cost of *US dollar* funding spikes during such episodes, when it is *European* banks which are constrained by quarter-end regulation?

Our work harmoniously resolves these questions and contributes to two main strands of the literature. First, it adds to the large literature that studies how financial frictions impact the market functionality, and in particular how intermediaries' constraints impact various OTC markets (Duffie (2017), Fleckenstein and Longstaff (2020), Du, Hébert, and Huber (2023)). We focus on regulatory frictions and how non-US institutions' holding of USD assets and hedging demand causes global imbalances (Liao and Zhang (2022), Bräuer and Hau (2022), Du, Hébert, and Li (2023), Du and Huber (2024)). We also add to an ongoing discussion of how economic outcomes such as cross-currency lending and international capital flows are linked to the basis (Becker, Schmeling, and Schrimpf (2023), Kubitza, Sigaux, and Vandeweyer (2024), Ben Zeev and Nathan (2024)).

We further contribute to the literature on CIP deviations, which, prior to the financial crisis, were attributed to frictions such as counterparty risk and funding shortages (Baba, Packer, and Nagano (2008), Mancini-Griffoli and Ranaldo (2013)). Post-crisis deviations have primarily been explained by intermediary constraints stemming from tighter bank balance sheet requirements (Ivashina, Scharfstein, and Stein (2015), Abbassi and Bräuning (2020), Krohn and Sushko (2022)). Rime, Schrimpf, and Syrstad (2022) show that low-credit quality banks struggling to obtain USD funding turn from wholesale to synthetic borrowing, where the dollar is supplied by high-credit quality banks. Our paper instead focuses on quarter-ends, and shows that substitution is driven by Eurozone banks which are constrained by the high regulatory cost of secured wholesale funding. Correa, Du, and Liao (2022) use data on US banks and study how their supply responds to potential arbitrage opportunities over balance sheet reporting periods; we focus instead on the behavior of non-US banks, which our globally representative data allows to do. Our paper is also related to Wallen (2022), who documents that US banks charge a premium for synthetic dollar funding due to European banks withdrawing from the FX swap market. In contrast, we demonstrate that European banks actually stay active in the FX swap market, increasing the demand for the dollar.

Our paper offers several key innovations: first, it explains how leverage ratio regulation affects the cross-currency basis, despite FX swaps ostensibly being exempt from such regulation (Borio, Iqbal, McCauley, McGuire, and Sushko (2018), BCBS (2014)). Second, it elucidates why demand for FX swaps surges at quarter-end. Third, it identifies substitution between repo and FX swap markets and provides a framework explaining how frictions in wholesale funding spill over into FX markets. Fourth, it offers evidence of inelastic demand for FX swaps among non-US financial institutions. Finally, it quantifies the realized portfolio positions related to FX swap trading across banking sectors by the nationality of their ultimate parent.

2. Wholesale and Synthetic Funding: Conceptual Framework

This section presents the regulatory landscape and pricing implications for US dollar funding that underpin the hypotheses we will empirically test.

2.1. Regulatory landscape

The first hypothesis we develop is that financial regulation prompts some non-US financial institutions to substitute US dollar funding from repos with FX swaps. Two mechanisms are at play. First, according to Basel III regulations, a bank must report its leverage ratio (LR), which is a risk-*unweighted* capital adequacy measure that particularly penalizes activities which expand the balance sheet, such as repo borrowing, with the result that balance sheet space comes at a higher opportunity cost. Importantly, however, differences in the implementation of Basel III *across jurisdictions* imply that some banks, particularly those of the Eurozone, are required to report their LRs as they stand at the end of the quarter while other banks, such as UK and US banks, calculate it using the average of the quarter's daily values. These different regulatory treatments have significant unintended effects for the regulation of financial institutions. For one, they encourage Eurozone banks to consistently 'window dress' their quarterly reports, thus portraying a more favorable financial picture to regulators than what is appropriate. The Basel Committee has labeled this behavior as 'unacceptable' and accordingly called for a regulatory reform (BCBS, 2018).[3]

A second artefact of banking regulation becomes apparent when we consider how regulation varies *across financial instruments* which may serve the same function. Consider the two primary methods for sourcing US dollar funding. The first is directly borrowing liquidity in US money markets via repo, while the second is to borrow US dollar indirectly, or synthetically, via the FX swap market by converting the available liquidity of a foreign currency, such as the euro, into USD. While economically similar, these two transactions have very different outcomes for a bank's Basel III LR. Regulation mandates that banks shall maintain a ratio of Tier 1 Capital to the Exposure Measure at a minimum threshold θ, with $\theta = 3\%$ for Eurozone banks at the group level:

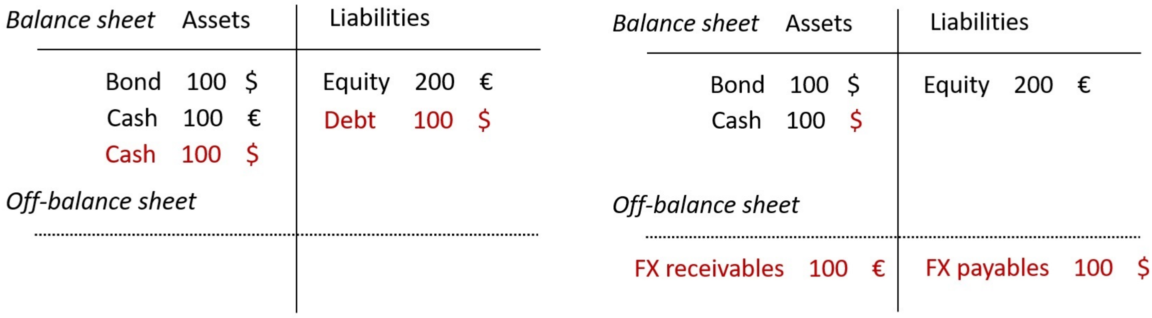
$$\text{LR} = \frac{\text{Tier 1 Capital}}{\text{Total Exposure}} \geqslant \theta \tag{1}$$

where Tier 1 Capital is Common Equity Tier 1 (CET1) plus Additional Tier 1 (AT1) instruments, and Total Exposure means on-balance sheet exposures, derivative and secured financing transaction (SFT) exposures, and, crucially, certain off-balance sheet items. Consider the simplified T-accounts in Figure (1) which depict the evolution of a bank's stylized balance sheet and its LR. A bank may raise short-term USD funding either with a repo as in panel (a), or through an FX swap in panel (b). The bank, say a large globally active French bank, begins with holdings of local currency (100 euro) and a US Treasury bond (worth 100 USD), and no debt, such that assets equal its net equity (200 euro, assuming a 1:1 exchange rate). With Tier 1 Capital of 200 and Total Exposure of 200, the LR is 1.0.

Suppose that this bank wishes to source USD by conducting a repo in US money markets. This expands the balance sheet, as a new position is created for the repo cash it has borrowed, matched by a liability denoting a future repayment obligation. As it receives the cash, it simultaneously lends out the collateral, say a US Treasury, which nevertheless remains on its balance sheet despite being exchanged.[4] While Tier 1 Capital remains unchanged, the Total Exposure measure increases

[3] In response to the window-dressing issues discussed in this paper, the Basel Committee on Banking Supervision has issued new guidance requesting that, as of January 2022 and for the purposes of Pillar 3 disclosure requirements, internationally active banks active must disclose the LR based on both quarter-end and quarter-average values of their gross SFT assets (BCBS, 2019). Banks located in the European Union have been subject to this more stringent disclosure as of 28 June 2021 (European Commission, 2021).

[4] See e.g. Ranaldo, Schaffner, and Vasios (2021) for the balance sheet implications of repo contracts.



(a) After repo: LR = 200/300 = 0.67.

(b) After FX swap: LR = 200/(200 + 0.01·100) = 0.995.

Fig. 1: Panel (a) depicts the evolution of the balance sheet after a repo transaction is conducted, and (b) does the same for an FX swap.

to 300, resulting in a decrease of the LR from 1 to 0.67.

Consider now the alternative of sourcing US dollar synthetically through an FX swap, i.e. by converting euro liquidity into US dollars. However, unlike a repo, FX swaps are an off-balance sheet instrument, and as such contribute to the LR through the "add-on factor" for potential future exposure; this means that 1% of FX swap positions counts towards the exposure calculation (Borio et al. (2018), BCBS (2014)).[5] Panel (b) of Figure (1) demonstrates how this impacts the balance sheet. The near leg of the FX swap simply converts the currency composition of the euro liquidity to USD. The far leg of the FX swap (the forward leg) increases both assets and liabilities, reflecting that the bank will have to repay the USD notional and will receive its original euro liquidity; however, this occurs off-balance sheet, and the LR becomes $200/(200 + 0.01 \cdot 100) = 0.995$. The advantage of the FX swap over a repo is thus clear: the latter drastically reduces the LR from 1 to 0.67, while an FX swap barely affects it, instead leaving it at a virtually unchanged 0.995.[6] Note that whether the bank has a starting capital of US Treasuries or of euro liquidity does not impact its decision, as it can convert to the other without affecting the LR.

Note that the secured nature of repo contracts creates additional costs relative to unsecured borrowing due to the requirement to either hold or obtain the appropriate collateral. Following

[5] Instead, FX swaps merely change the composition of the banks' on-balance sheet assets. Borio, McCauley, and McGuire (2020) write that when an "agent enters into an FX swap, using another currency as collateral, the new currency simply replaces the old one on the asset side of the balance sheet: the size of the balance sheet does not change… the debt remains 'hidden.'"

[6] There is one important exception whereby FX swaps lose their attractiveness relative to repo: year-ends. FX swaps are fully counted in the annual calculation of G-SIB capital surcharges (BCBS, 2013). When referring to quarter-ends in this paper, we are always referring to the three non-year-end quarter-ends. In section 4.3.3, we study the exceptional case of year-ends.

the implementation of Basel III regulation, US money markets underwent a reform in 2016 which resulted in a substantial reallocation of assets under management from prime funds to government funds.[7] This shift notably altered the nature of USD borrowing, transforming it from a primarily unsecured to a predominantly secured market, which particularly affected non-US banks (see Choulet (2018), Anderson, Du, and Schlusche (2021), Aldasoro, Ehlers, and Eren (2022)).

2.2. Pricing framework

Our second hypothesis is that the regulatory costs outlined in section 2.1 are priced. Specifically, market participants weigh the effective cost of borrowing between wholesale and synthetic funding, and substitute from one to the other until the price of an FX swap (i.e. the cross-currency basis) reflects the shadow cost differential between US and domestic wholesale markets. At the quarter-end, a widespread rise in the effective US repo borrowing cost transmits to a higher basis, consistent with the additional demand for FX swaps being inelastic.

To illustrate this effect, consider the CIP condition, which states that the return from lending in domestic currency should equal that of lending in foreign currency on a fully hedged basis. If an agent purchases a foreign currency at spot while simultaneously agreeing a forward agreement to return to his home currency, the returns from lending in the foreign money market must equal the return from investing in his home country.[8] If substantial enough, deviations from this principle represent an arbitrage opportunity. Thus, for currency pair $x|y$, we have:

$$(1 + i^{y}_{t,t+n}) = (1 + i^{x}_{t,t+n}) \cdot \left(\frac{F^{x|y}_{t,t+n}}{S^{x|y}_{t}} \right) \tag{2}$$

where n is the maturity under consideration, S_t represents the spot rate at time t, $F_{t,t+n}$ is the forward rate agreed for a trade unwinding at time $t+n$, and $i^{x}_{t,t+n}$ and $i^{y}_{t,t+n}$ represent the interest earned in the base and quote currencies respectively.[9] We refer to deviations from CIP as the

[7] Prime funds invest in public-sector securities, commercial paper, and certificates of deposit issued particularly by the private sector and non-US issuers. Government funds on the other hand invest in debt, including repo. Before the reform, both operated on a constant net asset value (CNAV) model, which caused adverse selection issues during crises. Instigated by the SEC, the reform entered into force on October 10, 2016 and obliged private funds to instead adopt a floating net asset value (VNAV) model, leading to a large reallocation from private to government funds.

[8] 'Spot' is an FX naming convention referring to the fact that whereas the transaction terms (and economic substance) of the trade are instantaneous, delivery of the currency occurs two days later, a time frame referred to as spot.

[9] The first three letters of a currency pair, e.g. EURUSD, are referred to as the base currency, and the last three

cross-currency basis; we take an increase in the basis to mean that borrowing USD has become more expensive. We thus have:

$$\chi^{x|y}_{t,t+n} = \left(\frac{F^{x|y}_{t,t+n}}{S^{x|y}_{t}}\right) \cdot (1 + i^{x}_{t,t+n}) - (1 + i^{y}_{t,t+n}) \tag{3}$$

The CIP condition held well empirically before the 2008 financial crisis (Akram, Rime, and Sarno, 2008), but broke down during the recession, and deviations have persisted ever since. This fundamental change has been largely attributed to intermediary constraints arising from a more stringent post-crisis regulatory landscape under Basel III. Du et al. (2018) show that deviations from the CIP principle are particularly high when an FX swap contract crosses the quarter-end, making USD borrowing via FX swaps more expensive (we replicate this effect in Appendix A). In the remainder of this section, we argue that the observed rise in the cross-currency basis is in fact consistent with no-arbitrage if one takes into account the increase in shadow cost of US repo borrowing. Thus, intermediary constraints emerge in wholesale funding markets, but spill over to synthetic dollar funding markets.

We illustrate such an effect by augmenting the CIP no-arbitrage principle with shadow costs. Setting $y = \$$ in eq. (2) states that the cost of borrowing in US money markets (l.h.s.) must equal the cost of raising domestic currency and swapping it into USD (r.h.s.). Expressed as such, the CIP principle is an expression of the law of one price (Rime et al., 2022), stating that the cost of borrowing dollars must stay equivalent regardless of whether it is conducted through wholesale or synthetic funding. We then incorporate various shadow costs C associated with wholesale funding, which include regulatory costs as well as other hidden costs such as haircuts, difficulties in obtaining the requisite collateral, etc.[10] We thus obtain:

$$\underbrace{(1 + i^{\$}_{t,t+n} + C^{\$}_{t,t+n})}_{\text{Cost of raising USD}} = \underbrace{(1 + i^{x}_{t,t+n} + C^{x}_{t,t+n})}_{\text{Cost of domestic funding}} \cdot \underbrace{\left(\frac{F^{x|\$}_{t,t+n}}{S^{x|\$}_{t}}\right)}_{\text{Cost of FX swap}} \tag{4}$$

Re-arranging the above in log-terms yields:

as the quote currency.

[10] There may also be a shadow cost to using an FX swap instrument; however, given that only 1% of these instruments enter the LR calculation, we simplify this cost to zero.

$$\underbrace{\left(i^{*,\$}_{t,t+n} - i^{*,x}_{t,t+n}\right)}_{\text{i-rate differential}} + \underbrace{\left(c^{\$}_{t,t+n} - c^{x}_{t,t+n}\right)}_{\text{shadow cost differential}} = \underbrace{\left(f^{x|\$}_{t,t+n} - s^{x|\$}_{t}\right)}_{\text{forward premium}} \tag{5}$$

which states that the forward premium is determined by the differentials in interest rates and shadow costs. Inserting eq. (3) shows that the cross-currency basis rises with the differential in shadow costs of borrowing USD in US money markets and that of raising domestic funding:

$$\chi^{x|\$}_{t,t+n} = c^{\$}_{t,t+n} - c^{x}_{t,t+n} \tag{6}$$

Our framework suggests that the basis will rise so as to make synthetic USD borrowing more expensive when there is an increase in the shadow cost differential, i.e. when USD repo borrowing becomes relatively costly w.r.t. non-USD borrowing. This is consistent with the dynamics we observe at the quarter-end. On the one hand, the shadow cost $c^{\$}_{t,t+n}$ rises for those banks reporting a snapshot of their supervisory ratios due to the mechanism described in section 2.1. Wholesale funding from US money market funds (MMFs) requires repo borrowing, which is costly from a LR perspective. On the other hand, non-USD borrowing can be readily conducted in non-US agents' domestic currency. Raising e.g. euro liquidity has been particularly easy during our sample period due to the ECB's unconventional monetary policy, which has resulted in high levels of central bank reserves, excess liquidity, and an enlarged domestic deposit base (Rime et al. (2022); similar arguments can be made for the monetary policies of Switzerland and Japan). Another ameliorating factor is the ECB's accommodating collateral policy (Corradin, Heider, and Hoerova, 2017), making it easy to source euro currency through repo. Meanwhile, the 2016 US MMF reform instead reduced the scope of non-US banks to obtain dollar unsecured funding. The resulting shift to secured borrowing requires non-US banks to source and pledge US Treasuries as collateral, which can be more difficult than obtaining euro repo funding, which is secured by an ample and heterogeneous set of collateral assets and conducted in market venues that allow for multilateral netting and risk reduction.[11] These dynamics are reflected in the cross-currency basis generally spiking so as to make synthetic USD borrowing more expensive.

This is naturally a simplified framework focusing on the shadow cost differential across money markets, with the consequence that we have abstracted away from a variety of alternative factors

[11] The quality of the euro repo market is discussed in Mancini, Ranaldo, and Wrampelmeyer (2016).

explaining the variation in the basis. Nevertheless, our framework provides intuitive insights. First, it highlights that the rise in the price of synthetic dollar funding, namely the cross-currency basis, reflects the increased regulatory cost of borrowing its substitute, wholesale funding. The intuition is that the law of one price implies that synthetic and wholesale dollar funding, being economically identical, must have the same effective price. When the average implicit cost of wholesale funding rises, the price of synthetic dollar funding adjusts to reflect this shift. Second, our framework suggests that it is the *differential* between the shadow costs of sourcing USD relative to domestic currency which impacts the basis. Third, when choosing their source of dollar funding, each individual agent in the market efficiently compares its own individual shadow costs relative to the market price for synthetic funding. The differential in shadow costs between direct and synthetic funding sources creates an upper bound on the market-wide cross-currency basis ($\bar{\chi}$) that each agent j is willing to pay to borrow in the FX swap market. The decision rule governing whether to substitute can be described as:

$$\text{Bank } j\text{'s funding choice} = \begin{cases} \text{Wholesale,} & \text{if } \bar{\chi}^{x|\$}_{t,t+n} \geqslant c^{j,\$}_{t,t+n} - c^{j,x}_{t,t+n}, \\ \text{Synthetic,} & \text{otherwise.} \end{cases} \tag{7}$$

To conclude, we provide a simple framework that links the cross-currency basis to the shadow cost differential between USD and domestic wholesale funding sources. Understanding the post-2015 landscape requires considering agents' funding shadow costs when considering this relationship. Quarter-end spikes in the cross-currency basis reflect that regulation disproportionately penalizes secured USD borrowing in US money markets (relative to domestic currency) for some of the largest market participants such as Eurozone banks. Those banks which find the cost of synthetic funding cheaper than the penalty from wholesale shadow costs accordingly substitute to FX markets. In a broader sense, the larger shadow costs of wholesale relative to synthetic dollar borrowing are severe frictions which are priced into equilibrium by intermediaries (Gabaix and Maggiori, 2015). Eurozone banks opting for synthetic dollar funding can also be interpreted as an attempt to minimize FVA, ensuring dollar funding at quarter-ends (Andersen et al., 2019).

3. Mapping the Market for USD Funding

This paper sheds light on the global US dollar funding chain through the lens of two crucial segments: FX swap and repo markets. To do so, we source novel settlement data to compare and contrast banks' synthetic funding positions (both gross and net) as well as the party-specific cross-currency basis costs they incur, taking into account potential heterogeneous pricing. We further complement this data with bank-level observations on wholesale markets. Subsection 3.1 describes the datasets and maps the flows of synthetic dollar funding while subsection 3.2 leverages the global nature of our data to demonstrate that swap positions reach their highest at the quarter-end, a crucial fact pattern which the rest of the paper seeks to explain.

3.1. Data description

3.1.1. Data on the global FX swap market

With their sheer size of around US$ 3.8 trillion of global daily turnover (BIS, 2022), FX swaps are the largest market in the world. However, obtaining representative data on this segment is notoriously difficult given its fragmented, over-the-counter nature. Trading occurs bilaterally and is dispersed throughout many exchanges, and relying on observations from a single source may not be representative of the global landscape. Our solution is to use data from CLS, the world's largest multi-currency cash settlement system.[12] Most if not all trades require settlement, and CLS allows us to observe trades regardless of where or on what platform (if any) they were executed.[13]

We obtain a bespoke dataset from CLS on quantities and prices allowing us to identify the actors in the FX swap market. First, we manually classify parties according to whether they are a global systemically important bank (G-SIB), a regular bank, or a non-bank. This allows us to capture and analyze the role of large dealers who dominate the FX market. Appendix B lists the G-SIB banks in our data.[14] Then, we manually sort the agents in our data set based on the

[12] CLS FX spot data has been studied before inter alia in Hasbrouck and Levich (2019), Ranaldo and Somogyi (2021), and Cespa, Gargano, Riddiough, and Sarno (2022), and CLS FX swap data has been analyzed in Bräuer and Hau (2022) and Kloks et al. (2023)

[13] There are some exceptions: for instance, CLS does not perform settlement for overnight swaps, the Chinese renminbi, or the Russian ruble. Moreover, a bank will not use CLS settlement when a customer has a deposit account with it (e.g., a retail investor using the banks' wealth management services). Furthermore, institutions (e.g., hedge funds) with a prime brokerage arrangement with a dealer-bank are not settled through CLS.

[14] We classified banks as G-SIBs if they were designated as such at least 7 times during the years 2012-2021

nationality of participants' ultimate parent.

Note that the *nationality* view, which we pursue in the subsequent analysis, is fundamentally different from the *locational* view. To give an example, J.P. Morgan's London branch would be classified as a US firm under the nationality view, as its balance sheet is denominated in US dollars, whereas it would be a UK firm from a locational perspective, as the trader sits in London. The intuition behind the nationality classification is to link banking groups with the currency in which their consolidated balance sheet is reported and in which they have a deposit base. Importantly, this further allows us to identify the regulatory framework to which they are subject. The nationality view recognises the importance of global financial intermediaries whose balance sheets go beyond national borders (BIS, 2024).

We manually classify 4,170 banking entities per group nationality. In case of ambiguity, we consulted the banks' investor reports and consolidated balance sheet reporting currency. We chose to sort banks into six regions of the world: the US, the Eurozone, the UK, Switzerland, Japan, and the rest of the world (ROW).[15] Our choice of regions results in our matching all G-SIBs with their home currencies (the dollar, the euro, the pound, the Swiss franc, and the yen). We further classify non-bank customers per geography. Funds were assigned to regions based on the physical location of the fund's management personnel, which avoids assigning them to the legal domicile of their headquarters, which may have little economic significance. Finally, corporates and non-bank financial institutions were assigned according to a location principle based on information observed in CLS.[16]

For a robustness check, we further obtained a sample of the CLS data set based on the locational principle, which is the principle that guides the BIS Triennial Central Bank Survey on FX and OTC derivatives (BIS (2016)). Table (1) reports the relative shares of the banking sectors by nationality in our data in comparison with BIS survey data. As can be seen, CLS and BIS coverage match closely based on the location principle, with both highlighting the role of London as the global hub for FX trading. This view severely underestimates the importance of US banks

according to the List of Global Systemically Important Banks (G-SIBs) published annually by the Financial Stability Board (FSB) in consultation with Basel Committee on Banking Supervision (BCBS) and national authorities.

[15] A welcome consequence of our classification system is that only Chinese banks are included in the ROW G-SIB bucket.

[16] Note that, in total, we have 6 currency blocks and 3 institution types, thus meaning that we have 18 distinct counterparties in our data set. We observe 138 directional flows (as non-banks cannot trade with each other in CLS, and inter-sectoral flows - e.g. Swiss G-SIBs trading with Swiss G-SIBs - cannot have a direction by definition).

which account for 47% of the market, while only 19% of trading occurs in the US. Eurozone and UK G-SIBs are the other major banking sectors, with 23% and 16% market share, respectively. To the best of our knowledge, we are the first to study CLS FX swap data based on nationality and institution type in a global context.[17]

Region	Location		Nationality
	BIS	CLS	CLS
UK	54	54	16
US	19	19	47
Eurozone	13	14	23
Japan	7	2	5
Switzerland	5	4	7
Other	3	6	2
Total (%)	100	100	100

Table 1: CLS and BIS coverage comparison. CLS data is based on a sample from 2016 and is benchmarked against the BIS Triennial Central Bank Survey of foreign exchange and OTC derivatives of that year.

Our data runs from from September 3rd, 2012 to June 30th, 2022 and is available at daily frequency. It covers 40 currency pairs (including 17 USD pairs) and 8 tenors[18] and captures at least 30% of the FX market according to BIS estimates (BIS, 2019). Table (C1) provides some summary statistics. For further analysis of the representativeness of CLS data, see Kloks et. al (2023).

Fig. (2) visualizes the global market for US dollar borrowing and lending in FX swaps through a network of outstanding positions using our CLS nationality data. For simplicity, we group our data into two main groups: G-SIB banks and customers, with the latter group including both regular banks and non-banks. We consider the net US dollar position between agents in *domestic* currency pairs.[19] The arrows represent the direction of the US dollar flow, with larger arrows representing greater net amounts of dollars being loaned. The color of the nodes sums up these positions to indicate an overall position in domestic currencies, with green (red) representing dollar lending (borrowing).[20] Finally, the size of the nodes is determined by agents' trading volume

[17] Kloks, McGuire, Ranaldo, and Sushko (2023) use this data to analyze how banks' FX swap positions compare with their balance sheet currency mismatches.

[18] We assign swaps to a total of 8 tenor buckets designed to represent tom-next, spot-next, 1-week, 2-week, 1-month, 2-month, 3-month, and longer maturities.

[19] That is, when considering a Japanese or a Swiss customer trading with a G-SIB, we calculate the dollar position based on USDJPY and USDCHF respectively. When a Eurozone G-SIB trades with e.g. a UK G-SIB, we consider the net dollar flow resulting from combining EURUSD and GBPUSD pairs. Focusing on domestic pairs allows us to parse out the effect of agents' using the dollar as a vehicle currency, and instead focus on fundamental flows.

[20] For simplicity, we do not include intra-customer flows in this analysis.

in all dollar pairs.

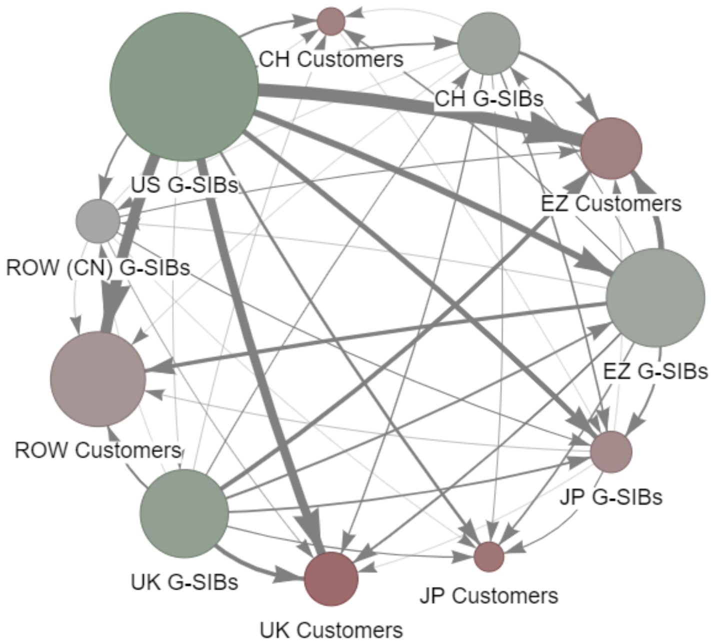


Fig. 2: The edges of the network show absolute net US dollar positions when considering participants' domestic currency pairs. The nodes' color represents the extent to which they are an overall dollar lender (green) or borrower (red) in their domestic currency pairs. Size of the nodes is determined by participants' trading volume in all dollar pairs. The plot is based on daily average positions and volumes for the 2012-2022 period.

Several conclusions emerge. First, the market is dominated by G-SIB banks, with *US* G-SIBs playing the most prominent role. Second, customers are clear net dollar *borrowers*, regardless of their nationality. Third, US G-SIBs are the most prolific dollar *lenders*, with large flows to all other agent types. Finally, US G-SIBs supply other G-SIBs with dollar *funding*, who in turn supply other participants. Indeed, while non-US G-SIBs such as Eurozone and UK banks borrow US dollar funding from their American counterparts, they are overall net dollar lenders due to their supply of such funding to non-G-SIB actors.[21] Appendix D provides a further volume breakdown per party, currency, and tenor while Appendix E quantifies the flows shown in Fig. (2) and shows them as a share of the underlying volume. For example, Eurozone banks are net USD borrowers from US G-SIBs in the domestic currency pair (EURUSD). The difference between dollar borrowing and dollar lending is 13.7% of the total EURUSD volume. All G-SIBs are significant dollar lenders

[21] Note that we cannot determine who instigated a trade; i.e. when a US GSIB supplies a Eurozone GSIB with USD in a EURUSD trade, we cannot tell whether the trade was initiated by the American (European) bank demanding euros (dollars). In other words, we cannot observe who is the "aggressor" or who triggered a market order, and thus this is not the classical order flow as studied in e.g. Evans and Lyons (2002).

to customers, reinforcing the notion that they actively intermediate and cater to the demand for dollar liquidity within their respective customer bases.

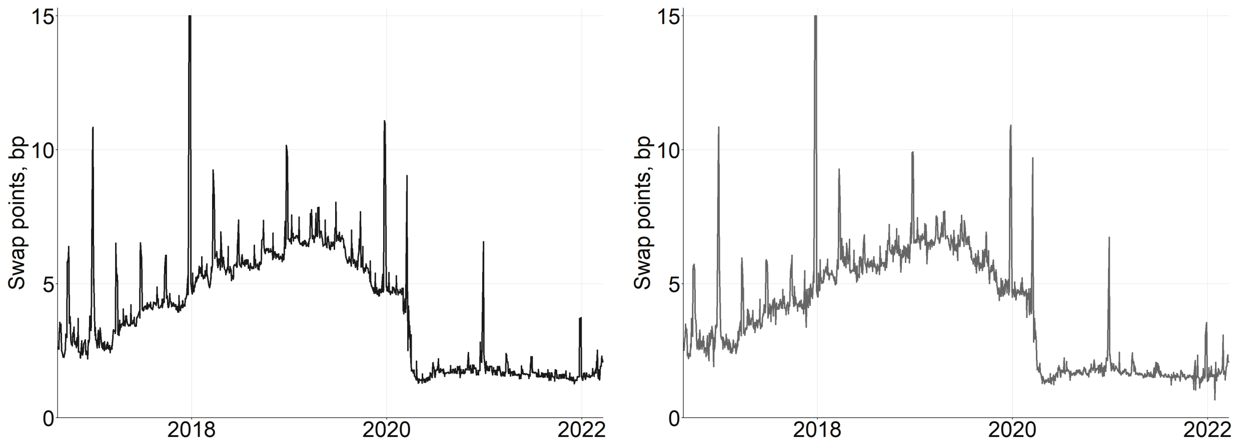
We further obtain data on FX swap prices, following the structure of our nationality dataset. We use swap points $F-S$, as they represent the *traded* price of an FX swap contract and reflect the conventional method by which FX swap prices are determined and exchanged. The implied rates of the near (S) and far (F) legs of each FX swap contract were manually and carefully matched. Then, daily volume-weighted average prices were calculated for each currency, tenor, party and counterparty. Figure (3) shows the actual prices charged by US banks based on CLS data, compared to indicative quotes from Bloomberg. It displays the volume-weighted average swap points $F-S$ for EURUSD 1W FX swaps traded on a given day by US banks across all counterparties, in comparison to the mid-quotes available on Bloomberg. The figure confirms that CLS rates, while naturally slightly noisier, are well-behaved and highly correlated with Bloomberg prices. To the best of our knowledge, we are the first to study FX swap prices using settlement data.

To obtain the cross-currency basis from FX swap points, we match the traded CLS rates with daily overnight interest rate swap (OIS) and LIBOR interest rates from Bloomberg. Due to data limitations, interest rate data is often only available for the G7 currency pairs in a historically reliable time series. Where needed, currency conversions to the US dollar are performed using Olsen spot exchange rates. Finally, for a comparison to CLS rates, we also obtain Bloomberg data on swap points for all the respective currency pairs.

3.1.2. Data on US and European repo markets

The global US dollar funding chain intricately links the activity of banks in several markets beyond FX swaps, most notably in the US repo market. We source data on US wholesale funding from reports on MMF portfolio holdings, provided by US Securities and Exchange Commission (SEC) form N-MFP (obtained from Crane data). The tri-party repo market contained therein is where large global banks, including non-US banks, obtain US dollar from MMFs, who are the largest primary cash lenders in this market. The data set includes outstanding repo volumes for US and non-US banks at an individual entity level and is available as a snapshot at each month-end from 2012 onwards.[22]

[22] US MMF borrowing is a sub-segment of the GCF repo market studied in Egelhof, Martin, and Zinsmeister (2017), who observe similar window-dressing dynamics as we do.



(a) Quoted swap points (Bloomberg)

(b) Traded swap points (CLS)

Fig. 3: EURUSD 1W swap points based on *quoted* swap points (Bloomberg, l.h.s.) vs. volume-weighted daily average *traded* swap points charged by US banks (CLS, r.h.s.). Note that the values of both series are capped at 15 basis points for better visualisation purposes. Data is daily from January 2017 until March 2022.

We further obtain data on Eurozone banks' activity in euro markets. We obtain data on all transactions that were executed on BrokerTec, the largest repo electronic exchange in Europe.[23] The data is daily and available to us at a bank level.[24] Since the European repo market is bank-dominated (Mancini et al., 2016), our data allows us to obtain a representative, even if imperfect, picture of Eurozone banks' trading activity in their home repo markets.[25]

3.2. Global quarter-end dynamics

Fig. (4) motivates our story, and provides the first evidence that the increase in quarter-end activity is linked to regulatory-driven demand effects. It shows that the daily surge in trading volumes peaks exactly at the end of the quarter, i.e. on the day t when the balance sheet is reported. Fig. (4) is an event study around quarter-ends for short-term *outstanding* FX swap positions. That is, an FX swap is included on date t if its near-leg settlement date $<= t$ and its

[23] Note that the European market structure is different as compared to the tri-party US repo market. Our European repo data come from the central (clearing) counterparty (CCP) based interbank market, which is the dominant segment in Europe.

[24] Importantly, although trading on BrokerTec is anonymous, we are able to classify market participants based on trader identification codes.

[25] Two other electronic trading platforms are prominent in Europe, namely Eurex Repo and MTS. Only MTS, which is primarily the market for Italian repos, is comparable in size to BrokerTec, but market participant identifiers are not available in MTS. Regardless, Italian banks do not play a large role in the global US dollar funding markets in comparison to either Eurozone or UK banks.

far-leg settlement date is $> t$.[26] Thus, the swap volumes appearing on date t are those volumes which would be shown on a bank's balance sheet for that quarter.[27]

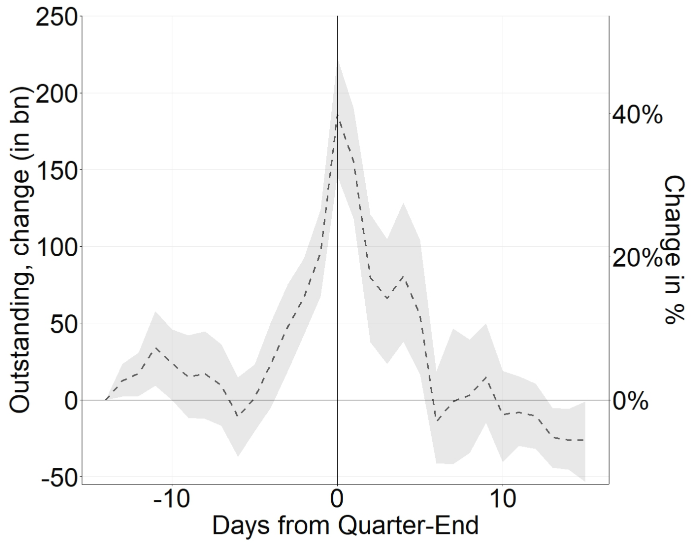


Fig. 4: Regulatory quarter-ends serve as the basis of the event study. Year-ends are not included. Short-term maturities means tenors between spot-next to 1W. All volumes are in USD. Dotted lines represent the 95% confidence interval with bootstrapped standard errors.

The plot depicts gross total global volumes and hence does not attempt to indicate a net borrowing pressure (which is investigated in-depth in the next section); instead, it clearly demonstrates that the surge in short-term volume at the quarter-end *intentionally* targets the reporting date itself; i.e., market participants seek to use FX swaps as part of quarter-end reporting concerns. Across all currency pairs, an extra US$ 200 billion worth of FX swap trades is conducted on average. The effect is substantial even when considering all FX swap tenors (not just the short-term segment); Appendix F shows that the spike in activity remains substantial and represents a 3% increase of total volume, especially once one takes into account International Monetary Market (IMM) dates.[28] Appendix G formalizes our findings in a regression setting and uses a difference-in-differences approach to confirm that these swaps *intentionally* target the quarter-end itself (as opposed to perhaps being caused by general volatility during the reporting period). For example, spot-next (tom-next) FX swap positions will see a surge in volume two (one) days before the quarter-end.

[26] The data set defines a business day as rolling over at 5 p.m. New York time, in line with FX convention.

[27] We consider regulatory quarter-ends, i.e. post-2015 quarter-ends (as public disclosure of the LR started in 2015 for European banks) and do not include year-ends.

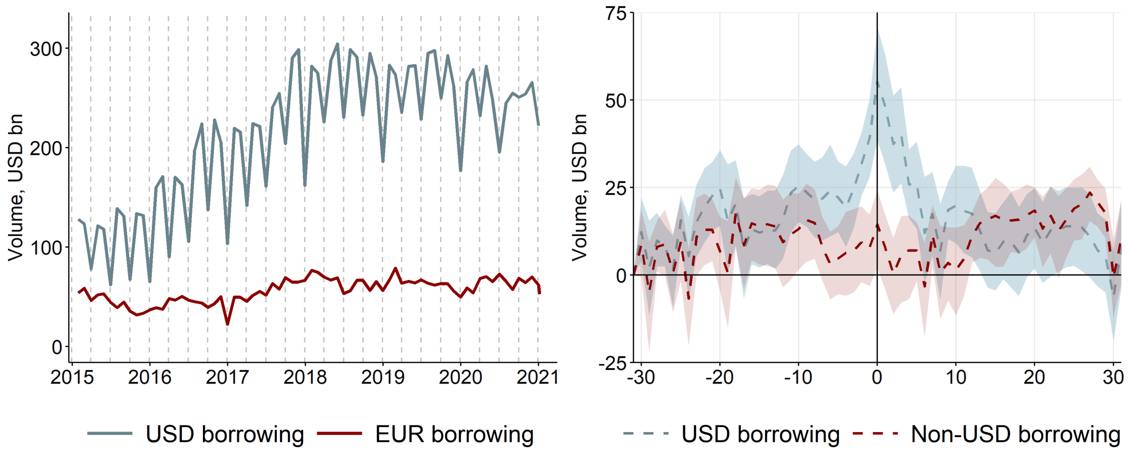
[28] When considering all tenors, we observe a remarkable drop in volume several days before the quarter-end; this occurs during the IMM dates when many swaps expire; see Appendix F for details.

4. Repo-FX Swap Substitution

In section 2.1, we explained how the two main money market instruments, i.e. repos and FX swaps, heterogeneously impact banks' balance sheets, and emphasized how FX swaps avoid hindering banks' regulatory ratios. Here, we empirically demonstrate how and why constrained banks substitute away from repo instruments to FX swaps when sourcing US dollar funding.

4.1. Empirical evidence of substitution

We begin by presenting visual evidence supporting the substitution hypothesis. Panel (a) of Figure (5) shows Eurozone G-SIBs' gross repo borrowing of USD (in blue) from US MMFs and euro borrowing (in red) in domestic money markets. It is clearly discernible that Eurozone banks systematically reduce their dollar borrowing in the US repo market by an order of magnitude of 50 billion USD during quarter-ends (denoted by dotted vertical lines). Euro repo borrowing, however, remains relatively constant.



(a) Repo

(b) FX swaps

Fig. 5: This figure shows the behavior of Eurozone G-SIBs in repo (l.h.s.) and FX swap (r.h.s.) markets. In panel (a), we see that Eurozone G-SIBs dramatically window-dress their US dollar borrowing, while non-USD borrowing remains relatively unchanged. In panel (b), we conduct an event study around quarter-ends (excluding year-ends) and see that USD swap borrowing surges, while euro borrowing remains unchanged. The time period runs from January 2015 to December 2020.

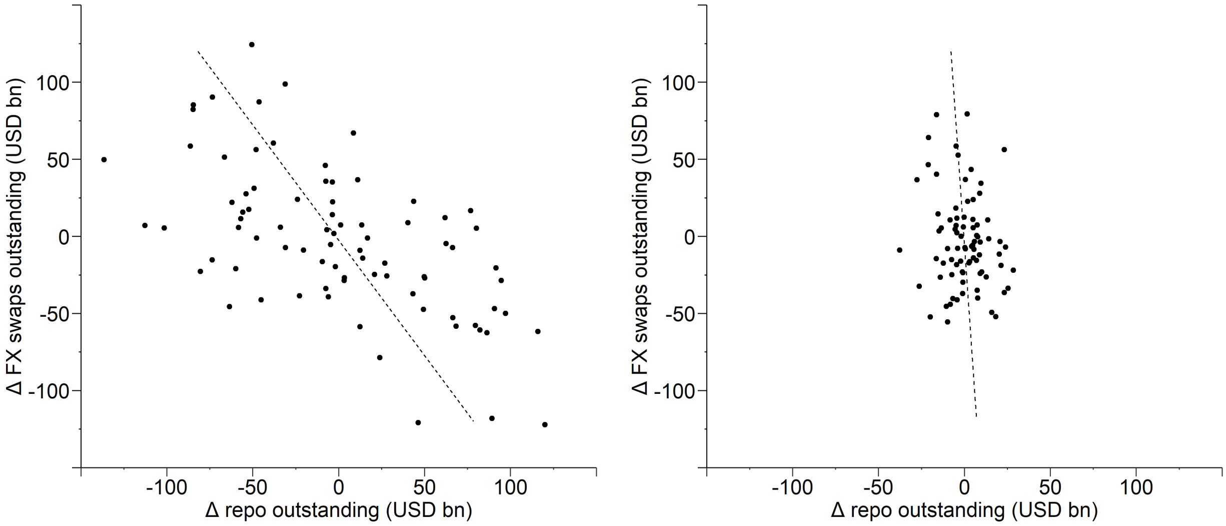
Panel (b) of Figure (5) essentially presents the mirror image of Panel (a). Specifically, it shows the FX swap patterns from an event study spanning 31 days before and after the quarter-end for

Eurozone banks (as a quarter spans 62 business days). We analyze the purchases of USD and euro separately across all currency pairs. Bootstrapped standard errors are depicted as a shaded area around the point estimates. The figure clearly shows that Eurozone G-SIBs' dollar borrowing through FX swaps significantly increases by a magnitude similar to the drop observed in the US repo market, whereas their euro borrowing (via FX swaps) remains constant.

Overall, Figure (5) shows that Eurozone banks significantly withdraw from the US repo market at quarter-ends, while simultaneously increasing their FX borrowing of US dollars through FX swaps by approximately the same amount. Our findings shed new light on global dollar funding in two key respects. First, our data enable us to analyze both borrowing and lending volumes via FX swaps, whereas other work such as Wallen (2022) could observe only net positions. Our findings clearly show that Eurozone banks increase their borrowing of USD at quarter-ends while maintaining their dollar lending largely constant, challenging the notion that Eurozone banks withdraw from the FX swap market at quarter-ends. Second, our findings provide a deeper understanding of the mechanisms which characterize the US repo market at quarter-ends. While it has been widely documented that non-US banks substantially decrease their dollar funding in the US repo market (Munyan, 2017), our joint analysis of repo and FX swaps suggest that non-US banks *substitute* the lost dollar funding from the US repo market with FX swaps, which represent an attractive alternative for regulatory reasons.

4.2. Identification: heterogeneous regulatory reporting

To rule out the possibility that the repo-FX swap substitution described above is coincidental rather than regulatory-driven, we refine the identification strategy by comparing those banking groups which report their regulatory ratios as a quarter-end snapshot with those which report daily averages of the quarter's values. As discussed in section 2.1, banking regulation in most jurisdictions mandates that ratios are calculated using the balance sheet as it stands on the last day of the quarter. Two jurisdictions, the UK and the US, are an exception. In the UK, banks first reported their quarterly ratios as an average of the three intervening month-ends during a transition phase from January to December 2016 (Cenedese et al. (2021)). Subsequently, they moved to a daily averaging scheme (Bank of England, 2015). The Supplementary Leverage Ratio (SLR) in the US has been based on daily averages since its inception. Figure (6) shows prima facie evidence that repo-FX swap substitution is an activity pursued by Eurozone G-SIBs (l.h.s.) but not their UK counterparts (r.h.s.). While a clear negative association is visible between (changes in) net USD FX swap positions and borrowing from US MMFs in US dollars for Eurozone banks (l.h.s.), this relationship does not apply to UK banks (r.h.s.).



(a) Eurozone G-SIB banks (b) UK G-SIB banks

Fig. 6: Repo-FX swap substitution. The figure displays monthly *changes* in Eurozone (l.h.s.) and UK (r.h.s.) net USD FX swap positions in all US dollar currency pairs vis-à-vis the monthly *change* in their borrowing from US MMFs. For both FX swaps and repos, values combine all maturities and are measured in bn of USD. The sample runs from January 2015 to September 2021.

We therefore use banks from snapshot-reporting jurisdictions as a treatment group - in that they are strongly incentivized to adapt their quarter-end results - and banks from jurisdictions on averaging schemes as a control group.[29] Note that this approach is likely to lead to an underestimation of the average treatment effect for the treated, given that "averaging" banks arguably still face some minor incentive to window-dress at the quarter-end. Further note that whether averaging was taken using daily values or monthly figures (as in the UK transition period) does not matter for our identification given our regression model, which is as follows:

$$Y_{i,t} = \beta_1 \cdot Q_t^{end} \; + \; \beta_2 \cdot Snapshot_i \; + \; \beta_3 \cdot Q_t^{end} \cdot Snapshot_i \; + \; \beta_4 \cdot Y_t^{end}$$
$$+ \; \beta_5 \cdot Q_t^{end} \cdot Y_t^{end} \cdot Snapshot_i + \alpha_i + u_{i,t} \tag{8}$$

where Q_t^{end} (Y_t^{end}) is a dummy indicating a quarter-end (year-end), α_i are ultimate parent na-

[29] Note that UK GSIBs are classified as snapshot reporters for the duration of 2015, and thereafter are labelled as "averagers."

tionality fixed effects, and $Snapshot_i$ is unity for snapshot-reporting bank nationalities and 0 for "averaging" banking jurisdictions. β_3 is the difference-in-differences estimator and the coefficient of interest, while the year-end variables serve only as controls. Regarding the dependent variable $Y_{i,t}$, we separately regress the volume of US dollars borrowed in FX swap and repo markets (in logs). We further calculate the share of USD borrowing which occurs through FX swaps as opposed to repo as follows:

$$SwapShare^{\$}_{i,t} := 100 \cdot \left(\frac{SwapBorrowing^{\$}_{i,t}}{SwapBorrowing^{\$}_{i,t} + RepoBorrowing^{\$}_{i,t}} \right) \tag{9}$$

Note that we are only considering the borrowing of US dollars in the dependent variable, be it in repo, FX swaps, or as a share.

	Snapshot vs. daily average reporters		
	FX swap (logs)	Repo (logs)	Swap Share (%)
	(1)	(2)	(3)
Q^{end}	-0.014	-0.093	1.644
	(0.055)	(0.096)	(1.731)
$Snapshot$	-0.266^{***}	-0.786^{***}	9.864^{***}
	(0.091)	(0.159)	(2.862)
$Q^{end} : Snapshot$	0.133^{**}	-0.355^{***}	7.310^{***}
	(0.066)	(0.121)	(2.183)
Controls			
$Q^{end} : Y^{end}$	-0.515^{***}	-0.025	-10.954^{***}
	(0.096)	(0.168)	(3.028)
$Q^{end} : Y^{end} : Snapshot$	0.153	0.008	5.867
	(0.114)	(0.209)	(3.756)
Observations	492	411	411
Adj. R^2	0.910	0.834	0.813

Table 2: All models are panel regressions with banking nationality fixed effects. Dependent variable is the amount of US dollars borrowed in FX swaps, in repo, and as a share as defined in eq. (9). "Snapshot" is a dummy variable comparing banking nationalities that report their regulatory ratios as a quarter-end snapshot (i.e. the Eurozone, Switzerland, Japan, and ROW) as opposed to banks which report averages (i.e. the UK and the US). Q^{end}_t (Y^{end}_t) is a dummy indicating a quarter-end (year-end). Frequency is monthly; the sample starts at the 2015 year-end and ends in September 2021. FX swaps volumes are amounts outstanding of dollars borrowed in CLS and repo volumes are amounts outstanding of USD borrowing from US MMFs (results are in logs).

The results in Table (2) provide support for our first hypothesis. When crossing the quarter-end, snapshot-reporting banks show a 14%[30] higher outstanding position in FX swap dollar borrowing than banks on an averaging scheme. In the US repo market, constrained bank volumes drop by 30% when crossing the regulatory period, as opposed to the control group. When considering FX swaps as a share of money market borrowing (i.e. swaps and repos combined), we see a statistically and economically significant surge of 7.3% relative to banks on an averaging scheme.

Note that this analysis, pooled over all banking groups in our sample, hides a considerable amount of heterogeneity across jurisdictions, which we will clarify in the ensuing section. The general picture that emerges, however, is that repo-FX swap substitution is driven by balance-sheet reporting concerns.

4.3. Additional analyses on repo-FX swap substitution

We conduct various additional analyses to further confirm our hypothesis. We consider substitution patterns across the following dimensions: (i) nationalities, (ii) currencies, (iii) year-ends, and (iv) secured v. unsecured funding.

4.3.1. Breakdown by jurisdiction

We further explore the results presented in section 4.2 and in particular study the heterogeneity across reporting jurisdictions' banking sectors. As discussed, there are three major G-SIB nationalities reporting on a quarter-end snapshot basis: the Eurozone, Switzerland, and Japan.[31] We replicate the differences-in-differences analysis using the model in equation (8) for each of these groups separately. Furthermore, we alternate between the UK and the US as the control group for each regression. Results are shown in the three tables of Appendix I.

Results show that the repo-FX swap substitution dynamic is strongest for Eurozone and Swiss G-SIBs. Compared to UK G-SIBs, Eurozone G-SIBs show a 17% higher outstanding position in FX swap dollar borrowing and a 12% relative drop in US repo markets when crossing the quarter-end. When considering FX swaps as a share of money market borrowing, we see a statistically and economically significant surge of 7.4% relative to UK G-SIBs. The dynamic is weakest for Japanese G-SIBs, where we only see a statistical rejection of the null when compared to the US control

[30] As the model is in log-linear form, a unit increase in the regressor causes a $100 \cdot \left(e^{\beta} - 1\right)$ percent increase in the dependent variable.

[31] We exclude Chinese (ROW) G-SIBs from the analysis, as they do not borrow repos from US MMF.

group, but not w.r.t. the UK. Indeed, our results imply that UK G-SIBs show some substitution dynamic relative to US G-SIBs.

Further evidence of the substitution link is evinced by the fact that those *same* nationalities which decrease their wholesale funding also increase their synthetic borrowing, as shown in Fig. (J1). That is, Eurozone and Swiss banks significantly decrease their repo borrowing and increase their FX swap borrowing, while other banks do neither (or relatively far less). Aldasoro et al. (2022) suggest that repo window-dressing is prevalent amongst European banks specifically because French banks in particular are large repo intermediaries with considerable matched book repo activity. US banks supply that synthetic dollar funding, but interestingly do not do so by increasing their US MMF borrowing. In Appendix K, we more formally test FX swap borrowing dynamics through a difference-in-differences regression for the three major G-SIB nationalities.

4.3.2. Uniqueness of the dollar

A second piece of evidence that the FX swap and repo movements we observe are not coincidental stem from the fact that they are particular to the US dollar. If all repo volumes regardless of currency decreased, it would be unclear why we should expect FX swap borrowing of *US dollars* to increase. Panel (a) of Figure (5) shows the time series of European banks' borrowing in domestic European repo markets as well as from US MMFs. These Eurozone banks clearly decrease their US dollar repo borrowing at quarter-ends, but do not do so nearly as much in European repo. We formalize the evidence shown in Figure (5) in Appendix L and in particular leverage the granularity of our bank-level data; our difference-in-differences analysis confirms that those *same* banks which pursue window-dressing in US money markets are not nearly as active in their domestic market.

4.3.3. Year-ends

At year-end, FX swaps lose their relative attractiveness w.r.t. repos (see Krohn and Sushko (2022)) due to the year-end G-SIB capital surcharges (BCBS, 2013), to which their positions fully contribute (as opposed to the usual 1% regime at regular quarter-ends). We should thus expect a reversion of repo-FX swap substitution at year-end relative to non-year-end quarter-ends. For each G-SIB group, we run a regression of the share of synthetic to total USD funding (as in eq. (9))

on quarter-end and year-end dummies (i.e. $SwapShare_{i,t} = \beta_0 + \beta_1 \cdot Q_t^{end} + \beta_2 \cdot Q_t^{end} \cdot Y_t^{end} + u_{i,t}$). Results are shown in Table (M1). While the composition of dollar funding shifts from wholesale to synthetic at non-year-end quarter-ends, it reverts for all participants at the year-end. For instance, Eurozone G-SIBs increase their share of synthetic borrowing by 12% at the quarter-end, but scale it back by almost 6% at the year-end. UK and US G-SIBs also noticeably scale back their year-end FX swap positions. In general, the reversion is not as large as the quarter-end increase. Despite the low number of observations in the regression, our results support the notion that the regulatory cost differential between wholesale and synthetic dollar funding determines agent's funding choice. When this differential is reduced or even reversed (such as at year-end due to regulatory requirements), banks tend to rely less on the latter source.

4.3.4. Secured v. unsecured funding

Finally, we investigate whether the window-dressing patterns in US money markets differ between secured and unsecured borrowing. Our prior belief is that secured funding is constrained due to its requiring collateral, which negatively impacts the LR and requires agents to own or source the appropriate security. While unsecured funding has its own disincentives stemming from the regulatory framework (such as the liquidity coverage ratio) and XVA costs, it does not require collateral. We estimate a bank-level difference-in-differences model comparing the outstanding amount of secured vs. unsecured US dollar borrowing by G-SIB banks at the quarter-end. As shown in Appendix N, no significant dynamics are observed for unsecured funding; secured borrowing is the focus of window-dressing efforts. Note that the 2016 US money market reform greatly reduced the supply of unsecured lending, and therefore USD borrowing became far more repo-driven. Appendix O shows that non-US unsecured borrowing suffered a precipitous drop of 600 B USD at the time of the reform, and was replaced by a surge in secured borrowing.

In total, these combined results support our hypothesis that non-US banks, especially Eurozone banks, *hunt for dollar liquidity* by replacing US repo dollar funding from US MMFs - which imposes a heavy regulatory burden - with synthetic dollar funding from the FX swap market, which only marginally expands the size of their balance sheets.

5. Pricing Analysis

In the previous section, we established empirical support for the volume dynamics underpinning our demand hypothesis. Here, we test whether the demand for FX swaps at quarter-ends has price effects which manifest through the cross-currency basis. We proceed in two steps: first, we study whether the demand for synthetic dollar funding is inelastic. Second, we quantify the economic impact of paying the cross-currency basis as a result of net USD borrowing at quarter-end across different market participant categories.

5.1. Non-US bank demand and basis effects

Mapping global dollar funding markets in section 3.1 suggested that US G-SIB banks are the primary suppliers of synthetic US dollar funding, while non-US G-SIBs constitute the demand side. Here, we investigate whether shocks to their demand, as proxied by a granular instrumental variable (GIV) approach (Gabaix and Koijen, 2024), are correlated with changes in the cross-currency basis, thereby providing evidence of a downward-sloping demand curve. To do this, we calculate, for each non-US-GSIB group i, currency x w.r.t. the dollar, maturity m, and trade date t, the daily *net* open position across all settled outstanding FX swap contracts l as follows:

$$\mathcal{O}^{Net}_{i,t,x,m} = \sum_{l=1}^{L} \mathbb{1}[\mathrm{T}_{i,t,x,m} = \mathrm{B}] \; - \; \mathbb{1}[\mathrm{T}_{i,t,x,m} = \mathrm{S}], \tag{10}$$

where B and S refer to trade direction and indicate whether a given traded volume T resulted in a dollar cash inflow or outflow at the near leg of the contract. The sum of net positions across all US dollar currency pairs and tenors yields for each non-US-GSIB group:

$$\mathcal{O}^{Net}_{t,x,m} = \sum_{i=1}^{I} \mathcal{O}^{Net}_{i,t,x,m}. \tag{11}$$

In a first step, we are interested in measuring the price elasticity of the cross-currency basis to changes in non-US-GSIB institutions' holdings of synthetic dollar funding, i.e. the change in their net FX swap outstanding positions. Consider the following equation:

$$\Delta \chi_{t,x,m} = \beta \cdot \Delta \mathcal{O}^{Net}_{t,x,m} + \epsilon_{t,x,m} \tag{12}$$

where $\mathcal{O}^{Net}_{t}$ is the net outstanding dollar borrowing of all institutions in our sample outside of US G-SIBs. We are interested in knowing whether the change in these outstanding positions (i.e.

swap flow) can impact the basis $\Delta\mathcal{X}_t$. However, endogeneity and reverse causality issues plague the estimation of eq. (12). GIVs provide a methodology to extract idiosyncratic shocks from flow data. The underlying intuition is that those idiosyncratic shocks which occur to large actors in the market are severe enough to affect the price (relevance condition). By virtue of their being idiosyncratic, however, they are not otherwise linked to price or e.g. macroeconomic variables (exclusion restriction). In the most simple case, these shocks are obtained by subtracting equal-weighted from size-weighted characteristics of agents within the market. In this section, we propose a GIV based on outstanding synthetic dollar holdings.

We consider the flow of all institution types which are not US G-SIBs (i.e., 17 parties, $i = 1, ..., N$) in the four main currencies (EURUSD, USDJPY, GBPUSD, and USDCHF) and in five different tenors m (TN, 1W, 1M, 3M, 1Y). For every currency x and tenor m, we have $\mathcal{O}^{Net}_{i,t} = \mathcal{O}^{\$}_{i,t} - \mathcal{O}^{x}_{i,t}$ where $O^{\$}_{i,t}$ and $O^{x}_{i,t}$ are outstanding positions whereby party i is borrowing USD and foreign currency, respectively. We form the building block of the GIV as: $Y_{i,t} := \frac{\mathcal{O}^{Net}_{i,t} - \mathcal{O}^{Net}_{i,t-1}}{|\mathcal{O}^{Net}_{i,t-1}|} \cdot 100$ and weights $S_{i,t-1} = \frac{\mathcal{O}^{\$}_{i,t-1}}{\sum_{i=1}^{N} \mathcal{O}^{\$}_{i,t-1}}$. In sum, we create a GIV for each of the 20 currency pair-tenor combinations in our sample.

Note that the main threat to identification is a failure to fully isolate idiosyncratic shocks, and instead letting aggregate shocks impact our estimate.[32] For example, a limitation of our identification is that the large agents in our setting are G-SIBs, and may thus be impacted by systemic effects specific to that fact. For example, they are all similarly affected by year-end G-SIB capital surcharges, which fully penalize FX swaps (see sec. 4.3.3). To mitigate such concerns, we consider various specifications of the GIV which control for such factors, and we further include variables such as quarter-ends and year-ends to soak up the effect of such aggregate shocks.

A further critical requirement of the GIV is that the industry is highly concentrated, such that there are major idiosyncratic shocks to exploit. We check this by considering the excess Herfindahl index of each currency pair-tenor, i.e. $h := \sqrt{-\frac{1}{N} + \frac{1}{T} \sum_{i=1}^{N} \sum_{t=1}^{T} S^2_{i,t}}$. An excess Herfindal index in the range of [0.2,0.7] is considered desirable; we obtain values within the range of [0.23,0.37], fulfilling this requirement. The GIV crucially depends on the extracting idiosyncratic shocks by considering the differences between size-weighted and equal-weighted shocks

[32] The main assumptions of the GIV approach are (1) granularity (with heterogeneous agent dimensions), (2) shock independence, (3) instrument validity, and (4) a lack of immediate feedback effects.

to agents' Y:

$$Y_S = \sum_{i=1}^{N} S_i Y_i, \qquad Y_E^{equi} = \frac{1}{N}\sum_{i=1}^{N} Y_i, \qquad Z^{equi} = Y_S - Y_E^{equi}. \tag{13}$$

The above GIV depends on weights $\Gamma = S - E$; however a more optimal version controls for correlation between shocks by using inverse-variance weights $\widetilde{E}_i$ such that:

$$\widetilde{E}_i := \frac{1/\sigma_{u_i}^2}{\sum_j 1/\sigma_{u_j}^2}, \qquad \widetilde{\Gamma}_i = S_i - \widetilde{E}_i, \qquad Z^{preci} = \sum_i \Gamma_i Y_i, \tag{14}$$

where Z^{preci} refers to the fact that this GIV uses precision-weighted quasi-equal weights. More refined versions of the GIV can be constructed by considering that the shocks may have a richer factor structure, with r factors, such that:

$$Y_{i,t} = \sum_{f=1}^{r} \lambda_i^f \eta_t^f + u_{i,t} \tag{15}$$

In order to estimate whether such common shocks exist, we run a principal component analysis (PCA) and extract the residuals as the basis for our new GIV. Encouragingly, the PCA reveals very few such common shocks, and the first component can barely explain more than $1/N$ share of the variance. In order to further cleanse our GIV from the impact of common shocks, we regress our building block $Y_{i,t}$ for each currency pair-tenor on the following:

$$Y_{i,t,x,m} = \alpha_i + \beta_1 \cdot s_{t,x} + \beta_2 \cdot VXY_t + \beta_3 \cdot TED_t + \beta_4 \cdot \mathcal{A}_{t,x,m} + \beta_5 \cdot Q_{t,m}^{end} + \beta_6 \cdot Y_{t,m}^{end} + u_{i,t,x,m} \tag{16}$$

where $s_{t,x}$ are log spot returns, VXY_t is the FX VIX, TED_t is the TED spread, $\mathcal{A}_{t,x,m}$ is the currency-tenor specific realized illiquidity measure of Kloks et al. (2023), and $Q_{t,m}^{end}$ ($Y_{t,m}^{end}$) refers to whether the underlying swap contract of that maturity crossed a quarter-end (year-end).

To ensure the robustness of our results, we consider four distinct GIVs: (i) Z^{equi}, based on equal-weighting as in eq. (13), Z^{preci}, based on precision-weighting as in eq. (14), Z^F, formed by size-weighting the residuals of eq. (16) and subtracting precision weights, and $Z^{P|F}$, which follows the same procedure as Z^F but first takes the residuals extracted from removing the first three principal components of each currency-tenor pair. We winsorize $Y_{i,t,x,m}$ at the 1% level and bound our GIV components and instruments to be within (-100,100).

The next step is to estimate equation (12) through two-stage least squares. Note that our independent variable here is the combined percentage net position of non-US-G-SIB institutions into the US dollar (which is supplied by US G-SIBs). We first check for instrument relevance (i.e. $\mathrm{E}[Z_{t,x,m}^{GIV} u_{t,x,m}] \neq 0$) for each currency x and tenor m and retrieve the fitted values $\widehat{\Delta\mathcal{O}}_{t,x,m}^{Net}$ for the second stage. Thus, we run first-stage regressions in the form of:

$$\Delta \mathcal{O}^{Net}_{t,x,m} = \beta \cdot Z^{GIV}_{t,x,m} + \gamma \cdot \mathbf{X}_{t,x,m} + \alpha_{x,m} + \tau_t + e_{t,x,m} \tag{17}$$

where $\alpha_{x,m}$ and τ_t are currency-tenor and day fixed effects, respectively, and $\mathbf{X}$ is a vector of controls.

Panel (a) of Table (3) reports results. We consider four specifications, one for each of our GIVs. We obtain a strong and significant first stage implying that a 1% increase in our GIV increases the change in agents' total net dollar holdings by 0.24% to 0.27%. We use the fitted values to estimate the second stage, which is equation (12) but with our instrument replacing the independent variable, i.e. $\Delta \chi_{t,x,m} = \beta \cdot \widehat{\Delta \mathcal{O}}^{Net}_{t,x,m} + \epsilon_{t,x,m}$.[33] The exclusion restriction $\mathrm{E}[Z^{GIV}_{t,x,m} \epsilon_{t,x,m}] = 0$ is given to us from the theory underlying GIVs: idiosyncratic shocks, cleansed of common shocks, can only impact the price through their direct transmission. Panel (b) of Table (3) presents results.

The first column presents a direct OLS regression of changes in the cross-currency basis on changes in outstanding positions (eq. (12)) and reveals no link between prices and flow. However, once we instrument flow (as proxied by changes in daily outstanding positions) with our GIV, we unveil a significantly positive link. Across our specifications, a 1% increase in flow results in a 0.54% to 0.93% increase in the basis. We are thus able support the notion that non-US-G-SIB agents act as the demand side w.r.t. to synthetic US dollar funding, as their flows have a significant price impact.

A back-of-the-envelope calculation shows that the economic magnitude of our price impact estimate is smaller than the average increase in the basis at quarter-end during our sample period. For instance, Eurozone G-SIBs, on average, increase their net quarter-end EURUSD 1W FX swap borrowing by 66.5%. Our price impact estimate implies that, ceteris paribus, CIP deviations should have spiked from 20bp to 28bp rather than to 66bp, which is the average realized basis

[33] Note that we calculate the cross-currency basis as follows:

$$\chi^{x|y,m}_t = 100 \cdot \left(i^{y,m}_t - \left(i^{x,m}_t - 100 \cdot \left(\frac{360}{m} \right) \cdot \left(-\log \left(F^{x|y,m}_t \right) + \log \left(S^{x|y}_t \right) \right) \right) \right), \tag{18}$$

$$\Delta \chi^{x|y,m}_t, \% = \frac{\chi^{x|y,m}_t - \chi^{x|y,m}_{t-1}}{\widehat{\chi}^{\,x|y,m}}, \tag{19}$$

where $i^{y,m}_t$ and $i^{x,m}_t$ are the compounded interest rates of the quote and base currencies, respectively. We take the cross-currency basis in differences as a percentage of the median value over the sample (i.e. as a percentage of $\widehat{\chi}^{\,x|y,m}$). The basis is often at zero; taking it as a share of its average over time avoids this issue.

Panel A: First Stage					
Dep. variable:		$\Delta\mathcal{O}_{t,x,m}$			
		$Z^{P/F}$	Z^{F}	Z^{preci}	Z^{equi}
		(1)	(2)	(3)	(4)
Z^{GIV}		0.27***	0.24***	0.25***	0.27***
		(0.03)	(0.03)	(0.08)	(0.05)
Panel B: Second Stage					
Dep. variable:		$\Delta\mathcal{X}_{x\|y,m,t}$, %			
	OLS	$Z^{P/F}$	Z^{F}	Z^{preci}	Z^{equi}
	(0)	(1)	(2)	(3)	(4)
$\Delta\mathcal{O}_{t,x,m}$	−0.12				
	(0.07)				
$\widehat{\Delta\mathcal{O}}_{t,x,m}$		0.54*	0.87**	0.93**	0.90**
		(0.29)	(0.34)	(0.34)	(0.33)
Controls	Yes	Yes	Yes	Yes	Yes
Fixed effects	$\alpha+\tau$	$\alpha+\tau$	$\alpha+\tau$	$\alpha+\tau$	$\alpha+\tau$
Clustering	$\alpha+\tau$	$\alpha+\tau$	$\alpha+\tau$	$\alpha+\tau$	$\alpha+\tau$
Observations	48,740	48,740	48,740	48,740	48,740
Adj. R^2	0.13	0.13	0.13	0.13	0.13

Table 3: The specifications are panel regressions over 4 currency pairs and 5 tenors, with currency pair-tenor and day fixed effects. Standard errors are also clustered by currency pair-tenor and day. Controls are $\mathbf{X} = \{\mathcal{A}_{t,x,m}, s_{t,m}, Q_t^{end}, Y_t^{end}\}$.

observed in the data. However, our price impact estimate was derived over the entire sample and is not specific to quarter-ends. Our results thus suggest that the quarter-end price impact surges, which is in line with the findings of Syrstad and Viswanath-Natraj (2022) and Kloks et al. (2023). A likely explanation is that constraints in wholesale markets are well-known, and thus order flow pressure for synthetic dollars signals constrained, inelastic demand. A first glance at the evidence corroborates this view. Figure (P1) shows a powerful correlation between the extent of repo window-dressing between Eurozone banks, and the size of the cross-currency basis. Figure (Q1) further shows a strong correlation between the share of secured borrowing from US MMFs, and the cross-currency basis. These analyses point to the link between constraints in US money markets and the basis.

We now turn our attention to supply and demand elasticities. Here, a stronger relevance condition is required, chiefly that $\mathrm{E}[\Delta\mathcal{X}_{t,x,m}Z_{t,x,m}^{GIV}] \neq 0$, i.e. demand shocks can impact the price.

We thus run regressions of the form:

$$\Delta\chi_{t,x,m} = \beta \cdot Z^{GIV}_{t,x,m} + \gamma^{\chi} \cdot \mathbf{X}_{t,x,m} + \alpha_{x,m} + \tau_t + \epsilon^{\chi}_{t,x,m} \tag{20}$$

Panel (a) of Table (4) presents the results of this first-stage. Significance is achieved on all versions of our GIV. We then extract the supply and demand elasticities, ψ and ϕ respectively, as follows:

$$Y^{S}_{t,x,m} = \psi \cdot \widehat{\Delta\chi}_{t,x,m} + \gamma^{S} \cdot \mathbf{X}_{t,x,m} + \alpha_{x,m} + \tau_t + \epsilon^{S}_{t,x,m} \tag{21}$$

$$Y^{E}_{t,x,m} = \phi \cdot \widehat{\Delta\chi}_{t,x,m} + \gamma^{Y} \cdot \mathbf{X}_{t,x,m} + \alpha_{x,m} + \tau_t + \epsilon^{Y}_{t,x,m} \tag{22}$$

Panels (b) and (c) in Table (4) display results for the supply and demand elasticity, respectively. Our GIVs suggest that in response to a 1% increase in the basis, US-GSIB dealers increase their provision of synthetic dollar funding by approximately 4-6% while non-US institutions decrease their dollar demand by 0.18% to 0.41%. Overall, these estimates suggest that the demand for synthetic dollar funding is more inelastic than its supply.

5.2. Quantifying the quarter-end basis cost

The econometric analysis conducted above has provided parametric estimates of the relationship between the cross-currency basis and transaction flows. However, these methods are better suited for capturing systematic relationships rather than those specific to particular market conditions, such as quarter-end dynamics. In the final part of our analysis, we compute simple (non-parametric) statistics based on traded prices and volumes from CLS data. To achieve this, we compute two simple measures that account for the different positions of the main market participant groups: (a) their per-dollar effective USD borrowing cost (in basis points) and (b) their CIP net income earned or lost (in millions of USD) from their FX swap business. We calculate these by combining data on each category's traded volumes with the actual FX swap points paid to execute those trades, with both data sets obtained directly from settlement data.

In particular, we express the effective USD borrowing cost γ as the volume-weighted average cross-currency basis paid across all contracts of currency j and maturity k traded on a given trading day t. The borrowing volume is defined as any trade where the respective agent receives USD at the near leg of the contract. The basis χ is calculated using the actual traded swap points $(F - S)$ obtained from settlement data on the FX side, and market-wide OIS interest rates obtained from Bloomberg on the interest rate side. We obtain the daily effective USD borrowing cost (in

Panel A: First Stage				
Dep. variable:	$\Delta\chi^{t,m,x}$, %			
	$Z^{P/F}$	Z^{F}	Z^{preci}	Z^{equi}
	(1)	(2)	(3)	(4)
Z^{GIV}	0.15*	0.21**	0.23**	0.24**
	(0.08)	(0.08)	(0.08)	(0.09)
Panel B: Second Stage - Supply				
Dep. variable:	Y_S			
	$Z^{P/F}$	Z^{F}	Z^{preci}	Z^{equi}
	(1)	(2)	(3)	(4)
$\Delta\chi_t^{x\|y,m}$, %	5.76***	4.09***	3.82***	3.78***
	(0.17)	(0.06)	(0.06)	(0.07)
Panel C: Second Stage - Demand				
Dep. variable:	Y_E^{preci}			
	$Z^{P/F}$	Z^{F}	Z^{preci}	Z^{equi}
	(1)	(2)	(3)	(4)
$\Delta\chi_t^{x\|y,m}$, %	−0.41***	−0.35***	−0.33***	−0.18***
	(0.17)	(0.06)	(0.06)	(0.07)
Controls	Yes	Yes	Yes	Yes
Fixed effects	$\alpha+\tau$	$\alpha+\tau$	$\alpha+\tau$	$\alpha+\tau$
Clustering	$\alpha+\tau$	$\alpha+\tau$	$\alpha+\tau$	$\alpha+\tau$
Obs.	48,740	48,740	48,740	48,740

Table 4: The specifications are panel regressions over 4 currency pairs and 5 tenors, with currency pair-tenor and day fixed effects. Standard errors are also clustered by currency pair-tenor and day. Controls are $\mathbf{X} = \{\mathcal{A}_{t,x,m}, s_{t,m}, Q_t^{end}, Y_t^{end}\}$.

basis points) by considering each agents' daily transactions across the G7 currency pairs:

$$\gamma_{t,i} = \frac{\sum_{j=1}^{J}\sum_{k=1}^{K}(Buy_{i,t,j,k}\cdot\chi_{i,t,j,k})}{\sum_{j=1}^{J}\sum_{k=1}^{K}Buy_{i,t,j,k}}. \tag{23}$$

The measure consolidates USD borrowing costs across all currencies and maturities into a single figure.[34] Naturally, each agent's effective cost depends on its FX swap portfolio and is expected to be higher for those agents who conduct more of their USD borrowing in currencies and/or tenors characterized by large CIP bases. Once such fixed effects are controlled for, the

[34] For example, a bank which borrows 1 million USD for one day at 100 basis points per annum and 1 million USD for one week at 50 basis points per annum has an effective daily borrowing cost of 75 basis points per USD in annualized terms.

per-dollar cost measure can also be interpreted as indicative evidence of price discrimination.

Column (1) of Table (5) reports the average effective USD borrowing cost (in basis points) across various agent groups for FX swaps most affected by the quarter-end turn (i.e. one day to one month tenors only). The results reveal that for swaps not affected by the quarter-end turn ('excl.Q^{end}'), effective borrowing costs are largely similar across agents, ranging from 26 basis points for non-US G-SIBs to 22 basis points for other non-US banks, on average. Since our primary interest lies in quarter-end effects, we compare the borrowing costs for contracts that cross the reporting dates, which are presented in column (2) in absolute terms and in column (3) as differences relative to regular (non-quarter-end) days. The results show that all market participants indeed incur a steep increase in realized borrowing costs due to the quarter-end effect; moreover, the dispersion in effective costs is much higher than during regular days. Japanese banks tend to borrow at the highest effective per-dollar cost, which is expected due to their portfolios being heavily concentrated in the yen-dollar pair (a basis-expensive currency pair). Furthermore, non-US G-SIB banks incur higher borrowing costs than US banks and even non-banks, possibly due to regulatory shadow costs. For Eurozone banks, the effective borrowing cost rises by 27 basis points on average, a magnitude similar to the average across the panel. At the same time, our results indicate that Eurozone banks do not suffer any substantial price discrimination compared to other non-US G-SIBs such as UK banks, despite a difference in regulatory shadow costs discussed in section 2.1. Our result is thereby in line with Rime et al. (2022) who argue that FX swap prices are homogeneous in the inter-dealer market.[35]

As a second measure, we compute the *additional* CIP net income earned or lost (in millions of USD) due to the quarter-end turn. This question is challenging to answer because the observed data reflect the total realized profit, which includes income that would have been made irrespective of the quarter-end. To isolate the quarter-end effect, we need to establish a counterfactual. We do this by estimating what each agent's CIP net income would have been if the affected FX swap trading volumes and prices had aligned with the pre-quarter-end trend.[36] For FX swap trades which crossed the quarter-end and were conducted on day t for currency j and maturity

[35] We confirm no evidence of substantial price discrimination in a number of further analyses (not displayed here) where we control for currency and tenor fixed effects.

[36] Specifically, we replace the net realized quarter-end volumes (buy minus sell) and basis charged with their average values over the 20 days preceding the quarter-end at the currency-tenor level, calculated as $\overline{Net_t} = \frac{\sum_{n=t-1}^{t-20} Net_n}{N}$ and $\overline{\chi}_t = \frac{\sum_{n=t-1}^{t-20} \chi_n}{N}$.

k, the additional CIP income earned or lost can then be computed as the difference between the realized and the counterfactual income:

$$\Delta\pi_{i,t} = \sum_{j=1}^{J}\sum_{k=1}^{K}(Net_{i,t,j,k} \cdot \chi_{i,t,j,k} - \overline{Net}_{i,t,j,k} \cdot \overline{\chi}_{i,t,j,k}) \cdot \frac{n}{N}. \tag{24}$$

For any given year, the total additional CIP earned or lost due to the quarter-end turn is then the sum of the respective daily values across all G7 currencies $\Delta\pi_i = \sum_{t=1}^{T}\Delta\pi_{i,t}$, which is then averaged over all our sample to obtain a yearly additional CIP income loss or gain in absolute US dollar terms.[37]

Column (4) of Table (5) reports the total yearly net CIP income (π) across all the FX swap business (all maturities from one day to one year) while columns (5) to (8) refer to the change in income ($\Delta\pi$) due to the quarter-end turn (based on affected maturities only, i.e. one day to one month). A positive (negative) sign indicates an expected cross-currency basis earned (lost). In total, non-banks emerge as the largest total net CIP basis payers, accumulating cash outflows of up to 17.2 billion USD per year, on average.[38] In contrast, banks receive the basis, which is expected and underscores the compensation they require for intermediating US dollar liquidity in FX swaps. Among all banks, US G-SIBs earn the most - 7.2 billion USD annually - confirming their role as key suppliers of USD liquidity.

As regards to the additional basis received or paid due to reporting date effects, column (7) reports the estimates on the net profit for all FX swap contracts affected by the quarter-end (one day to one month). Note that the net result is a sum of additional basis payments for USD purchases, in column (5), and additional basis income due to USD sales, in column (6). Our data reveal that the quarter-end turn results in large additional cash payments to obtain the dollar (4.7bn USD for all non-US G-SIBs combined); however, the additional cost is mostly passed on to end-customers so that the net cost is comparatively small. Non-G-SIB banks outside the US emerge as the largest beneficiaries, earning an additional net income of 0.5bn of USD per year on average.

As a final step, we examine the additional basis earned or lost from the change in agent's positions in short-term tenors over the quarter-end, which is distinct from total profitability and

[37] Note that the annualized expected cash flow is translated into a realized cash flow by applying a fraction of $\frac{n}{N}$, where n is the maturity of the FX swap, and $N = 365$.

[38] This calculation is obtained by first summing daily net incomes over all calendar trading days in each year across all currencies, tenors, and counterparties, which is then averaged over seven years and divided by 0.3, reflecting the share of CLS-settled FX swaps in the global FX swap market, according to a comparison with BIS data.

allows us estimate of the additional costs associated with short-term 'window-dressing' due to repo-FX swap substitution. Results are depicted in column (8) of Table (5). For example, Eurozone banks accumulated a CIP net positive income of up to 2.4 billion USD per year on average from 2015 to 2022. However, this net income would have been higher if not for the 37 million USD lost in basis payments due to excess short-term borrowing at the quarter-end. The results show that non-US G-SIB banks collectively lose approximately 74 million USD annually due to such short-term positioning around the quarter-end, whereas US dealer banks emerge as the largest CIP earners. The data also reveal that non-banks do not engage significantly in short-term FX swaps, with most basis cash inflows and outflows occurring in the interbank market. This is expected, as short-term FX swap trading is primarily associated with interbank liquidity management needs (Kloks et al. 2023).

	Effective cost γ (bp)			CIP income (mn of USD)				
	excl.Q^{end}	at.Q^{end}	Δ bp	Net	Δ Buy	Δ Sell	Δ Net	Δ $Net_{Rp\text{-}Swp}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Non-US G-SIB banks	26	56	30	3,562	(4,674)	4,476	(197)	(74)
Eurozone	25	52	27	2,429	(1,604)	1,735	131	(37)
Swiss	24	55	31	692	(820)	699	(121)	(17)
Japan	37	78	41	(5,197)	(399)	277	(122)	(15)
UK	24	50	27	3,893	(1,557)	1,378	(179)	(11)
China	23	49	26	1,745	(294)	387	93	6
Other non-US banks	22	48	26	6,497	(1,672)	2,158	486	10
Non-Banks	22	46	24	(17,220)	(859)	744	(115)	(2)
US G-SIB banks	24	52	26	7,261	(3,911)	3,936	25	65

Table 5: Estimates based on settlement data. Columns (1) to (3) refer to the effective cost (in basis points) for USD purchases while columns (5) to (8) refer to the additional CIP earned or lost from the quarter-end turn due to changes each agents' positioning and changes in the cross-currency basis charged to accumulate those positions. Column (4) reports the total CIP net income from all the FX swap business combined for comparison. Column (8) considers only the effects from the change in positioning in short-term tenors (one day to one week) so as to arrive at the cost of repo-FX swap substitution. For the CIP income values are yearly aggregates. Data combines the G7 currency pairs. Calculations are based on daily data from 2015 to 2022.

From these economic estimates, we can draw at least two key considerations. First, the net losses are relatively small compared to the usual business size of the G-SIB dealer banks. Even if synthetic dollar funding appears to be at a deficit, it might be efficient for banks to roll over their dollar funding to ensure the continuity of other business activities. Second, it might be more cost-effective for a bank to secure dollar funding synthetically because the quarter-end shadow cost burden of wholesale funding via US repos is heavier compared to synthetic dollar funding. In the spirit of Gabaix and Maggiori (2015), the CIP basis arises because intermediary frictions related to wholesale dollar funding are priced.

The effects on the CIP basis due to regulatory shadow costs align closely with the FVA principle (Andersen et al., 2019). For instance, consider the 37 million USD in additional yearly costs that estimated for Eurozone G-SIBs. This figure can be compared to the hypothetical cost of capital that Eurozone banks would need to pay if they continued borrowing through repos and sourced additional equity. Given our earlier finding that Eurozone excess borrowing in FX swaps amounts to approximately 50 billion USD per quarter, and assuming that a minimum of 3% of capital would need to be allocated for it under the LR at a return of 10% per year, this translates to a capital cost (in cash flow terms) of 150 million USD per year (50 billion x 0.03 x 0.10). In other words, the cost of holding equity year-round is several times larger than the extra basis paid for a few days around the quarter-end. While there may be other costs associated with holding FX swaps, such as hedging costs, our results indicate substantial net savings for Eurozone banks due to repo-FX swap substitution.

6. Conclusion

Our research has been motivated by a desire to better understand the channels of global dollar funding. We have studied how financial intermediaries obtain dollars from two major sources: US wholesale funding markets and FX swaps. First, we mapped global dollar funding activity by analyzing novel and granular data on institutions' operations across these two markets. Second, we demonstrated that, at quarter-ends, financial regulation incentivizes non-US banks to substitute dollar funding through US repos with FX swaps. This additional demand for FX swaps is particularly driven by Eurozone banks, which reduce their use of US repos due to the regulatory LR they must report as it stands at the end of the quarter. Third, we examine the price effects of repo-FX swap substitutability, providing evidence that the demand for swaps is inelastic and that regulatory shadow costs have a significant impact on the CIP basis.

The findings of our study have significant implications for both academics and policymakers. For academics, our research provides a deeper understanding of the mechanics of global dollar funding, in particular the hitherto unexplored link between wholesale and synthetic dollar markets, and shows how spillovers in the former impacts the latter. For policymakers, our results highlight the unintended consequences of current regulatory frameworks, suggesting that adjustments to these policies, particularly to the methodology of G-SIB surcharges, could help mitigate distortions in global funding markets. Our research highlights the precarious nature of dollar access, and how the microstructure of money markets can threaten the easy transmission of the dollar to non-US actors. Moreover, our paper underscores the importance of coordinated policy tools, such as central bank swap lines, in promoting financial stability and market efficiency.

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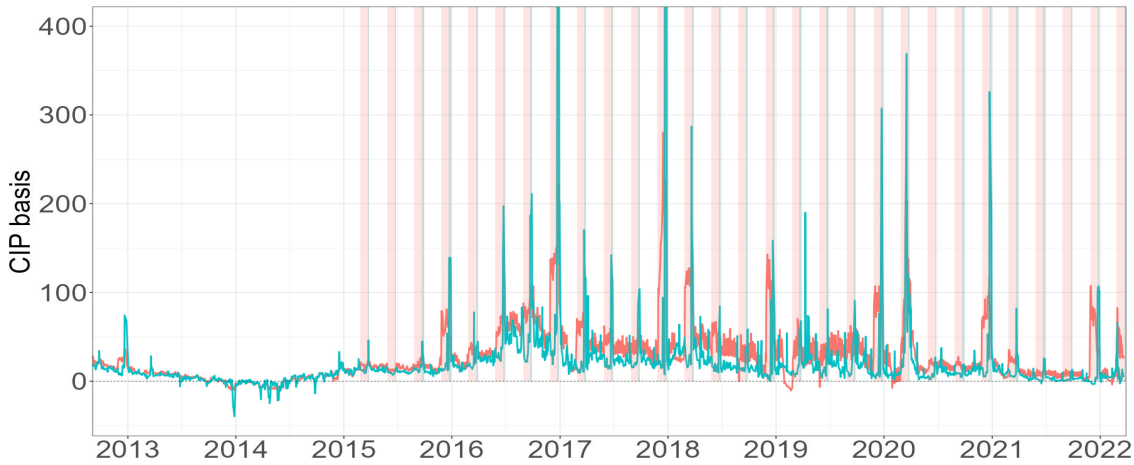
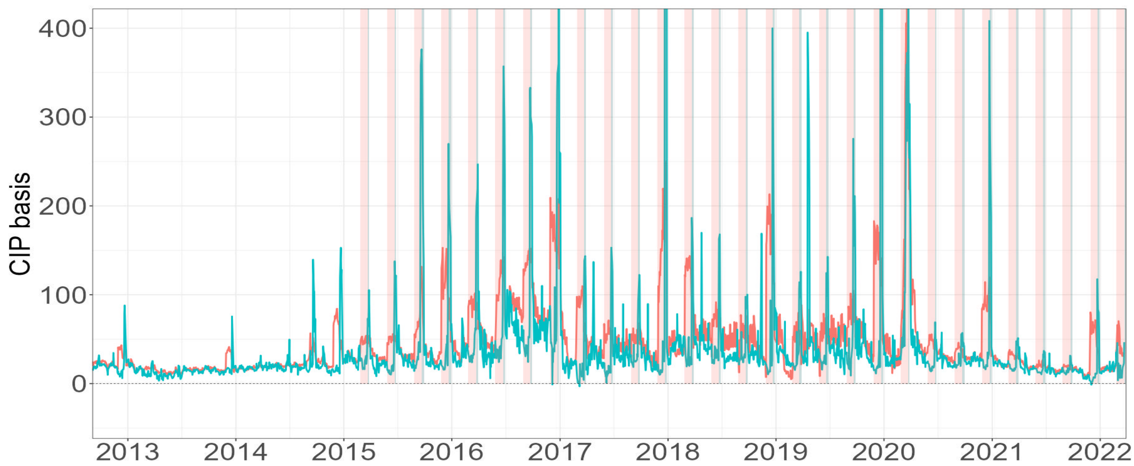
Appendix A



(a) EURUSD



(b) USDJPY

Fig. A1: Charts of the CIP basis for EURUSD and USDJPY. Red (blue) lines refer to the 1M (1W) basis. Red (blue) rectangles denote the business days when 1M (1W) repo contracts cross a quarter-end, starting from Q1 2015 until Q1 2022. Values are capped for presentational purposes.

Appendix B

Region	G-SIB
United States	Bank of America
	Bank of New York Mellon
	Citigroup
	Goldman Sachs
	JP Morgan Chase
	Morgan Stanley
	State Street
	Wells Fargo
Eurozone	BNP Paribas
	BPCE Groupe
	Crédit Agricole
	Deutsche Bank
	ING Bank
	Santander
	Société Générale
	UniCredit
United Kingdom	Barclays
	HSBC
	Standard Chartered
Japan	Mitsubishi UFJ FG
	Mizuho FG
	Sumitomo Mitsui FG
Switzerland	Credit Suisse Groupe
	UBS
ROW (China)	Agricultural Bank of China
	Bank of China
	China Construction Bank
	Industrial and Commercial Bank of China

Table B1: List of G-SIBs in our dataset, by region. Banks were classified as G-SIBs if they were designated such at least 7 times during the years 2012-2021 according to the List of Global Systemically Important Banks published annually by the Financial Stability Board.

Appendix C

The table below presents the descriptive statistics of the bespoke FX swap volume data from CLS used for this paper.

	Volume (in tn $)	Trades ('000)	Volume (%)	Trades (%)
EURUSD	4.75	77,940	37.4	30.9
USDJPY	2.54	31,963	20.0	12.7
GBPUSD	1.66	30,401	13.1	12.0
USDCHF	0.54	10,346	4.2	4.1
Other dollar	3.20	101,893	25.2	40.3
Maturity <= 7 days	0.87	7,413	6.9	2.9
Maturity > 7 days	11.82	245,129	93.1	97.1
Bank to Bank	10.15	155,951	80.0	61.8
Bank to Non-Bank	2.54	96,591	20.0	38.2
Involves a G-SIB Bank	11.83	230,444	93.2	91.2
w/o a G-SIB Bank	0.86	22,098	6.8	8.8
Total	12.69	252,543	100	100

Table C1: FX swap outstanding open positions of dollar pairs: 2012-2022 daily averages.

Appendix D

		TN	SN	1W	2W−1M	1M	1M−3M	3M	3M+	∑
G-SIBs	US	519	120	195	328	1435	1,233	1,883	3,567	9,280
	EZ	246	54	97	163	619	487	794	1,827	4,287
	UK	217	41	73	132	580	469	742	1,376	3,630
	CH	120	23	42	83	348	309	448	685	2,058
	JP	52	8	14	28	110	91	179	423	905
	Other	47	11	16	40	209	147	244	439	1,151
	∑	1,200	256	437	774	3,301	2,736	4,289	8,317	21,310
Small banks	US	4	1	1	6	55	17	23	47	154
	EZ	90	16	33	46	127	130	268	506	1,217
	UK	41	8	21	51	127	145	205	456	1,053
	CH	30	4	10	17	47	40	57	104	308
	JP	47	8	10	21	75	59	109	253	583
	Other	248	39	77	119	455	450	827	1,418	3,632
	∑	461	76	152	259	885	841	1,489	2,785	6,947
Non-Banks	US	3	1	6	27	410	241	195	385	1,268
	EZ	11	3	6	10	149	63	216	87	546
	UK	5	2	4	11	179	135	179	182	698
	CH	0	1	7	6	28	14	15	50	120
	JP	0	0	0	0	3	1	1	6	11
	Other	4	2	5	10	61	74	123	218	498
	∑	24	9	28	64	829	529	730	929	3,141

Table D1: FX swap open (outstanding) **total** volumes (dollar purchases **plus** sales), 2012-22 daily average, in bn of USD.

		EUR	JPY	GBP	CHF	AUD/NZD/CAD	SEK/NOK/DKK	Other dollar	∑
G-SIBs	US	3,039	2,056	1,316	434	741	396	1,296	9,280
	EZ	1,782	817	485	193	265	136	609	4,287
	UK	1,158	701	606	174	241	119	631	3,630
	CH	639	356	239	315	177	91	240	2,058
	JP	172	533	44	9	31	5	111	905
	Other	258	221	244	48	84	27	269	1,151
	∑	7,048	4,685	2,935	1,173	1,539	775	3,155	21,310
Small banks	US	36	24	40	5	30	4	14	154
	EZ	773	90	82	82	28	20	141	1,217
	UK	380	147	257	58	74	40	98	1,053
	CH	79	18	18	171	6	4	12	308
	JP	125	285	42	12	29	4	85	583
	Other	872	410	318	72	542	557	861	3,632
	∑	2,265	974	758	400	710	629	1,210	6,947
Non-Banks	US	433	319	192	30	101	29	164	1,268
	EZ	448	18	41	10	10	4	15	546
	UK	251	56	275	35	36	9	36	698
	CH	38	3	2	72	2	0	4	120
	JP	0	11	0	0	0	0	0	11
	Other	98	33	21	7	99	132	108	498
	∑	1,267	440	532	153	248	175	326	3,141

Table D2: FX swap open (outstanding) **total** volume (dollar purchases **plus** sales), 2012-22 daily average, in bn of USD.

Appendix E

		G-SIBs						Banks						Non-Banks					
		US	EZ	UK	JP	CH	ROW (CN)	US	EZ	UK	JP	CH	ROW	US	EZ	UK	JP	CH	ROW
G-SIBs	US	–	13.7	2.6	24.2	24.3	20.1	24.2	2.6	-5.4	24.6	0.9	10.0	-4.8	68.5	78.2	97.7	86.5	70.3
	EZ	-13.7	–	-9.1	18.0	9.1	9.2	-88.7	-2.4	-19.7	42.8	18.9	13.6	-37.2	66.1	75.8	100.0	96.6	83.1
	UK	-2.6	9.1	–	31.9	24.0	6.3	89.9	-1.7	3.0	43.3	2.7	3.3	-5.5	66.1	70.0	86.3	96.5	82.5
	JP	-24.2	-18.0	-31.9	–	-71.1	-86.6	n.a.	71.6	86.5	38.0	-100.0	26.8	n.a.	n.a.	n.a.	93.8	n.a.	n.a.
	CH	-24.3	-9.1	-24.0	71.1	–	51.3	96.7	1.8	-40.5	73.3	-9.0	-4.2	11.9	83.3	76.9	n.a.	92.6	82.7
	ROW (CN)	-20.1	-9.2	-6.3	86.6	-51.3	–	-89.4	4.8	-26.2	96.9	77.6	-13.8	12.1	74.6	80.9	n.a.	100.0	92.5
Banks	US	-24.2	88.7	-89.9	n.a.	-96.7	89.4	–	n.a.	-100.0	n.a.	-100.0	-71.4	-58.8	95.2	100.0	n.a.	n.a.	n.a.
	EZ	-2.6	2.4	1.7	-71.6	-1.8	-4.8	n.a	–	8.2	49.0	29.9	-5.7	n.a.	99.6	n.a.	n.a.	n.a.	n.a.
	UK	5.4	19.7	-3.0	-86.5	40.5	26.2	100.0	-8.2	–	75.3	38.2	-15.9	-11.0	95.3	93.1	n.a.	n.a.	91.0
	JP	-24.6	-42.8	-43.3	-38.0	-73.3	-96.9	n.a.	-49.0	-75.3	–	98.5	-52.2	100.0	n.a.	n.a.	n.a.	n.a.	n.a.
	CH	-0.9	-18.9	-2.7	100.0	9.0	-77.6	100.0	-29.9	-38.2	-98.5	–	-10.7	n.a.	n.a.	n.a.	n.a.	100.0	n.a.
	ROW	-10.0	-13.6	-3.3	-26.8	4.2	13.8	71.4	5.7	15.9	52.2	10.7	–	25.5	87.0	80.2	100.0	76.8	84.5
Non-Banks	US	4.8	37.2	5.5	n.a.	-11.9	-12.1	58.8	n.a.	11.0	-100.0	n.a.	-25.5	–	n.a.	n.a.	n.a.	n.a.	n.a.
	EZ	-68.5	-66.1	-66.1	n.a.	-83.3	-74.6	-95.2	-99.6	-95.3	n.a.	n.a.	-87.0	n.a.	–	n.a.	n.a.	n.a.	n.a.
	UK	-78.2	-75.8	-70.0	n.a.	-76.9	-80.9	-100.0	n.a.	-93.1	n.a.	n.a.	-80.2	n.a.	n.a.	–	n.a.	n.a.	n.a.
	JP	-97.7	-100.0	-86.3	-93.8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-100.0	n.a.	n.a.	n.a.	—	n.a.	n.a.
	CH	-86.5	-96.6	-96.5	n.a.	-92.6	-100.0	n.a.	n.a.	n.a.	n.a.	-100.0	-76.8	n.a.	n.a.	n.a.	n.a.	–	n.a.
	ROW	-70.3	-83.1	-82.5	n.a.	-82.7	-92.5	n.a.	n.a.	-91.0	n.a.	n.a.	-84.5	n.a.	n.a.	n.a.	n.a.	n.a.	–

Table E1: The table shows the net dollar position of participants with each other, considering domestic currency pairs. Figures are daily average net outstanding positions (dollar purchases minus sales) as a percentage of underlying volume. A positive number represents dollar lending from the row party to the column party.

Appendix F

Figure (F1) shows event studies of outstanding volume around quarter-ends for all tenors combined. In the l.h.s. graphic, we observe a remarkable drop in volume several days before the quarter-end; this occurs during the International Monetary Market (IMM) dates when many swaps expire. Money market instruments and currency / interest rate futures and options traded at the Chicago Mercantile Exchange have standardized expiration dates set as the third Wednesday of the month ending a quarter. As many medium-term (e.g. 3-month) FX swaps are used to access these products, we see a very strong decrease on those particular dates. Because of their timing, the number of days between an IMM date and a quarter-end date differs; the blue shading in the l.h.s. figure highlights the set of IMM days. This movement is not evidence of any window-dressing and instead is an artefact of the common expiry date applied to many swaps. The rhs image shows the same with a reduced window (7 days before/after the quarter-end) to remove the effect of the IMM period; we observe a US$ 500 billion surge, representing 3% of the outstanding market.

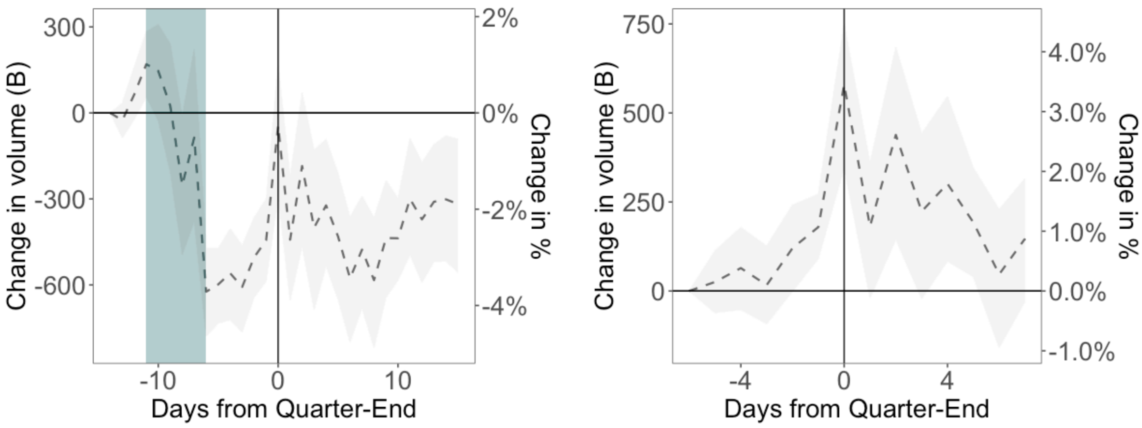


Fig. F1: Event studies around regulatory quarter-ends (year-ends not included). All tenors combined. Lhs shows the influence of IMM dates (shaded blue) when many swaps expire. Rhs starts the event study after the IMM date and shows a US$ 500 billion increase.

Appendix G

We now formally test whether banks purposefully trade swaps to have them appear on balance sheet reporting dates (thus repeating the exercise in Kloks et al. (2023) with our new data). An alternative explanation could be that quarter-ends are an important period for many actors and and it should perhaps be no surprise that we see a general increase in market activity, which may be linked to volatility or other conditions. To test this we run a a difference-in-differences analysis leveraging our *flow* data as well as variation in an FX swap's maturity. For example, a 1-week FX swap traded one week before the quarter-end will appear on the balance sheet, but a tomorrow-next swap traded on that same day will not. Thus, if banks are in general interested in using their FX swaps at the quarter-end, we would expect the 1-week swap trading to increase relative to tom-next swaps on that day. We thus estimate difference-in-differences models for the spot-next (SN) and 1-week (1W) tenors as the treated group with tomorrow-next (TN) swaps as our control group. That is,

$$TradedVol_{i,t} = \beta_1 \cdot Tenor_i + \beta_2 \cdot PreQ_t^{end} + \beta_3 \cdot Tenor_i \cdot PreQ_t^{end} + \beta \cdot \mathrm{X_{i,t}} + \alpha_i + u_{i,t}\,, \quad \text{(G.1)}$$

where $TradedVol_{i,t}$ is the amount of FX swaps of currency pair i traded on date t in logarithms, $Tenor_i$ is a dummy variable which is 1 if a swap contract has a spot-next (1-week) maturity and 0 if it has a tomorrow-next tenor, $PreQ_t^{end}$ is a dummy indicating whether SN (1W) swaps traded on that day crossed the quarter-end, α_i are currency pair fixed effects, $\mathrm{X_{i,t}}$ are controls, and $Tenor_i \cdot PreQ_t^{end}$ is the difference-in-differences estimator and the coefficient of interest.

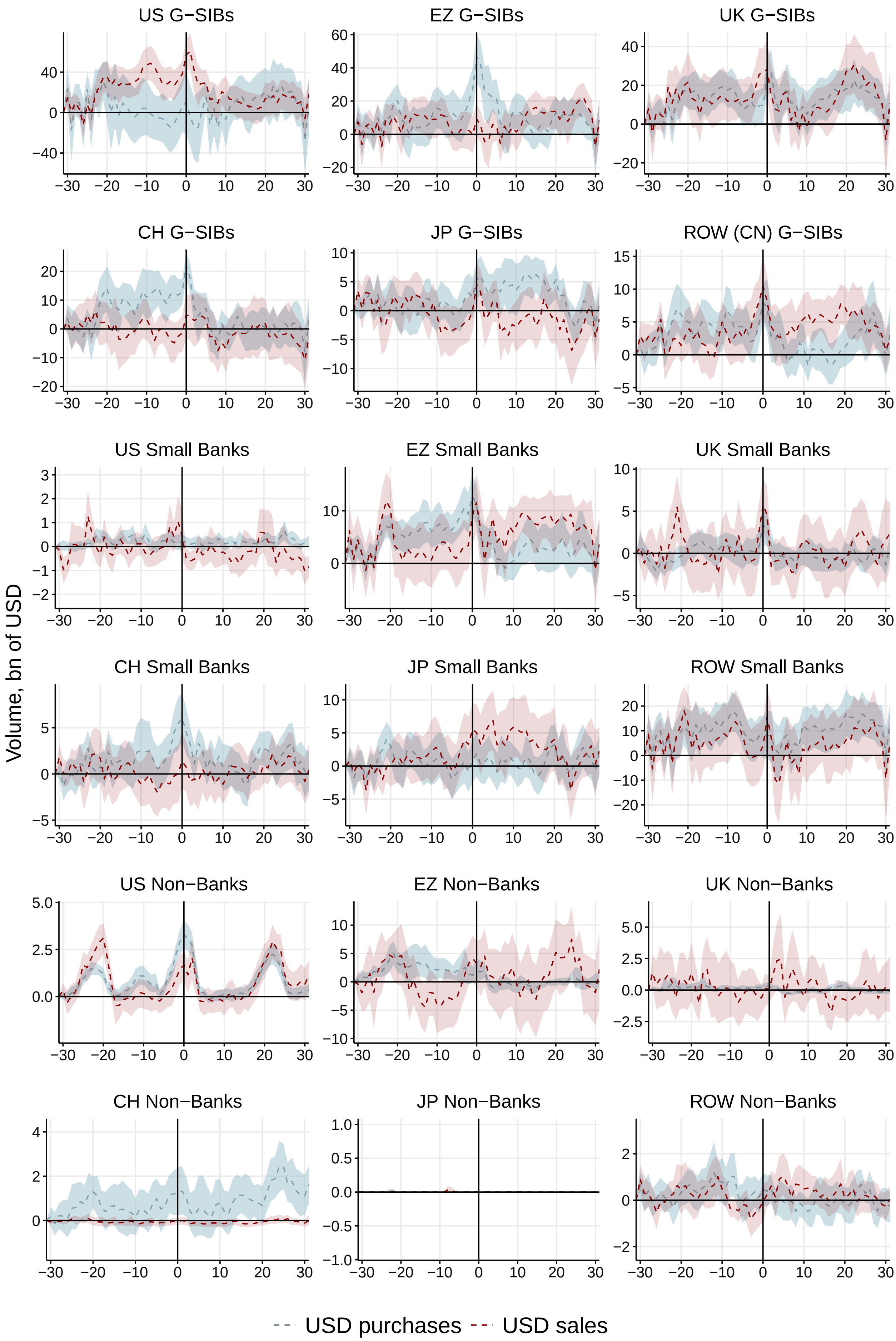
Table (G1) shows our results. Our results are economically and statistically significant for banks' trading, signifying that banks' increase 1-week swap trades one week before the quarter-end relative to tomorrow-next swaps (which would not appear on the balance sheet). That this mechanism also applies to spot-next swaps vs. tom-next swaps further emphasizes that these trades are driven by balance-sheet purposes only, and are not the result of general volatility.

	Banking volume (logs)					
	Spot-next			1-week		
	EURUSD	USDJPY	All	EURUSD	USDJPY	All
$Tenor$	-1.92^{***}	-1.85^{***}	-2.45^{***}	-2.13^{***}	-2.42^{***}	-2.81^{***}
	(0.06)	(0.05)	(0.12)	(0.04)	(0.05)	(0.13)
$PreQ^{end}$	-0.05	-0.06	0.05	-0.05	-0.12^{**}	-0.01
	(0.06)	(0.05)	(0.04)	(0.05)	(0.05)	(0.02)
$Tenor : PreQ^{end}$	0.39^{***}	0.34^{***}	0.38^{**}	0.47^{***}	0.68^{***}	0.33^{***}
	(0.12)	(0.12)	(0.15)	(0.10)	(0.10)	(0.07)
Constant	Yes	Yes	No	Yes	Yes	No
Currency FE	No	No	Yes	No	No	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,918	2,764	40,556	3,203	3,076	34,187
Adj. R^2	0.74	0.73	0.84	0.80	0.79	0.71

Table G1: Regressions (1) - (3) perform difference-in-differences estimation by comparing the spot-next and tomorrow-next tenors; (4) - (6) do the same with the 1-week and tomorrow-next tenors. Regressions for EURUSD and USDJPY are OLS models with Newey-West standard errors. (3) and (6) are panel regressions on all available currency pairs, for which fixed effects and clustered standard errors are applied. Banking volume is the amount of FX swaps of currency pair i traded by banks on date t in logarithms, $Tenor_i$ is a dummy variable which is 1 if a swap contract has a spot-next (1-week) maturity and 0 if it has a tomorrow-next tenor, $PreQ_t^{end}$ is a dummy indicating whether SN (1W) swaps traded on that day crossed the quarter-end, α_i are currency pair fixed effects, and the coefficient of $Tenor_i \cdot PreQ_t^{end}$ is the difference-in-differences estimator. Controls are for month-ends and year-ends ($\beta \cdot \mathrm{X_{i,t}} = \beta_4 \cdot PreM_t^{end} + \beta_5 \cdot PreY_t^{end} + \beta_6 \cdot PreM_t^{end} \cdot Tenor + \beta_7 \cdot PreY_t^{end} \cdot Tenor$, where $PreM_t^{end}$ ($PreY_t^{end}$) is a dummy indicating whether swaps traded on that day crossed the month-end (year-end)). The superscripts $***$, $**$ and $*$ indicate significance at the 1%, 5%, and 10% significance levels respectively.

Appendix H

The figure on the following page plots event studies or all 18 groups in our dataset. We center the event study 31 days before and after the quarter-end (as the quarter-end lasts 62 business days). We show dollar sales and purchases separately and, for each of them, show the bootstrapped standard errors as a shaded area around the point estimates. The years under consideration are 2015-2021 as this was the period when repo-FX swap substitution was most in effect. All volumes are in USD. Shaded area represents the 90% confidence interval with bootstrapped standard errors.



US G−SIBs
EZ G−SIBs
UK G−SIBs
CH G−SIBs
JP G−SIBs
ROW (CN) G−SIBs
US Small Banks
EZ Small Banks
UK Small Banks
CH Small Banks
JP Small Banks
ROW Small Banks
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JP Non−Banks
ROW Non−Banks
Volume, bn of USD
USD purchases
USD sales

	Eurozone G-SIB USD borrowing					
	vs. UK banks			vs. US banks		
	FX swap (logs)	Repo (logs)	Swap Share (%)	FX swap (logs)	Repo (logs)	Swap Share (%)
	(1)	(2)	(3)	(4)	(5)	(6)
β_0	4.983***	4.252***	67.06***	5.955***	5.120***	69.48***
	(0.037)	(0.103)	(1.26)	(0.040)	(0.040)	(0.89)
Q^{end}	0.038	−0.163***	4.11***	−0.052	−0.031	−0.39
	(0.056)	(0.052)	(1.48)	(0.055)	(0.044)	(0.93)
EZ	0.089**	1.264***	−27.82***	−0.848***	0.193***	−24.46***
	(0.039)	(0.061)	(0.87)	(0.048)	(0.026)	(2.11)
$Q^{end} : EZ$	0.156***	−0.117**	7.39***	0.199***	−0.307***	11.93***
	(0.057)	(0.049)	(1.53)	(0.054)	(0.067)	(1.68)
Controls						
$Q^{end} : Y^{end}$	−0.535***	−0.170	−7.93**	−0.532***	0.013	−12.51***
	(0.099)	(0.202)	(3.65)	(0.082)	(0.093)	(2.20)
$Q^{end} : Y^{end} : EZ$	0.040	−0.114	2.80	0.098	−0.150	5.53
	(0.106)	(0.114)	(2.38)	(0.100)	(0.103)	(3.92)
Observations	140	140	140	218	218	218
Adj. R^2	0.326	0.758	0.765	0.740	0.138	0.633

Table I1: All models are OLS with Newey-West standard errors. Dependent variable is the amount of US dollars borrowed in swaps, in repo, and as a share as defined in eq. (9). Models (1)-(3) use UK G-SIBs as a control, (4)-(6) use US G-SIBs. Q_t^{end} (Y_t^{end}) is a dummy indicating a quarter-end (year-end) and EZ_i is unity for Eurozone banks and 0 for UK (US) banks. Frequency is monthly; the sample starts in the 2015 year-end when considering UK banks and September 2012 when considering US banks, and ends in September 2021. FX swaps are volumes outstanding of dollars borrowed in CLS; repo volumes are amounts outstanding of USD borrowing from US MMFs.

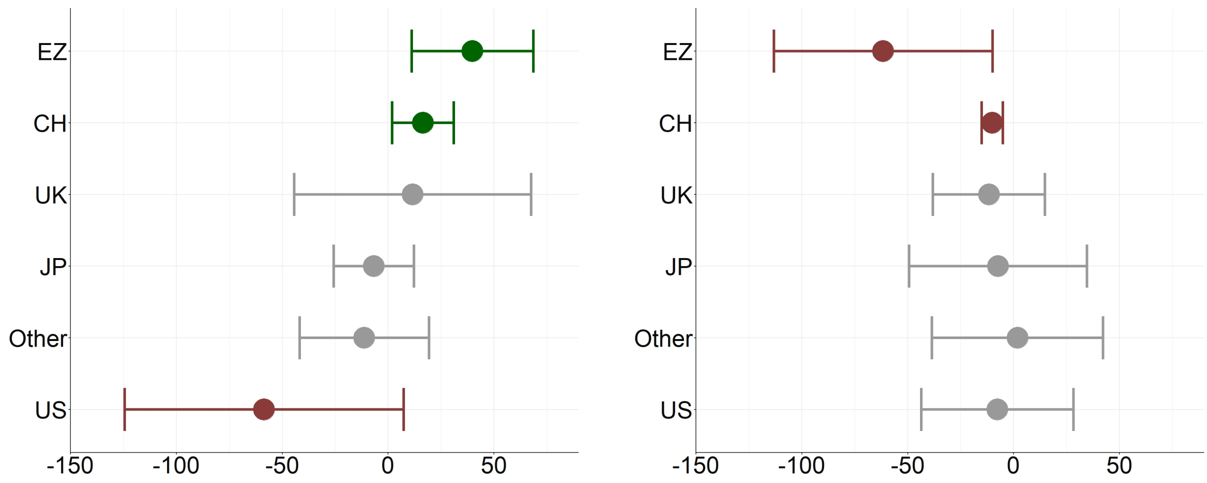
	Swiss G-SIB USD borrowing					
	vs. UK banks			vs. US banks		
	FX swap (logs)	Repo (logs)	Swap Share (%)	FX swap (logs)	Repo (logs)	Swap Share (%)
	(1)	(2)	(3)	(4)	(5)	(6)
β_0	4.983***	4.252***	67.06***	5.955***	5.120***	69.48***
	(0.041)	(0.078)	(1.28)	(0.043)	(0.041)	(0.71)
Q^{end}	0.038	−0.163**	4.11***	−0.052	−0.031	−0.39
	(0.042)	(0.074)	(1.49)	(0.048)	(0.026)	(1.09)
CH	−0.437***	−1.647***	18.53***	−1.40***	−2.250***	13.01***
	(0.039)	(0.168)	(2.25)	(0.046)	(0.129)	(1.16)
$Q^{end} : CH$	0.076*	−0.785***	5.00***	0.189***	−0.616***	7.79***
	(0.045)	(0.151)	(1.93)	(0.055)	(0.133)	(1.47)
Controls						
$Q^{end} : Y^{end}$	−0.535***	−0.170	−7.93**	−0.532***	0.013	−12.51***
	(0.107)	(0.252)	(3.86)	(0.082)	(0.094)	(2.28)
$Q^{end} : Y^{end} : CH$	0.201*	0.446	3.32	0.239**	0.163	7.97***
	(0.107)	(0.276)	(3.91)	(0.120)	(0.332)	(2.88)
Observations	140	140	140	218	218	218
Adj. R^2	0.531	0.796	0.703	0.881	0.843	0.607

Table I2: All models are OLS with Newey-West standard errors. Dependent variable is the amount of US dollars borrowed in swaps, in repo, and as a share as defined in eq. (9). Models (1)-(3) use UK G-SIBs as a control, (4)-(6) use US G-SIBs. Q_t^{end} (Y_t^{end}) is a dummy indicating a quarter-end (year-end) and CH_i is unity for Swiss banks and 0 for UK (US) banks. Frequency is monthly; sample runs from September 2012 to September 2021. FX swaps are volumes outstanding of dollars borrowed in CLS; repo volumes are amounts outstanding of USD borrowing in US MMFs.

	Japanese G-SIB USD borrowing					
	vs. UK banks			vs. US banks		
	FX swap (logs)	Repo (logs)	Swap Share (%)	FX swap (logs)	Repo (logs)	Swap Share (%)
	(1)	(2)	(3)	(4)	(5)	(6)
β_0	4.983***	4.252***	67.058***	5.955***	5.120***	69.481***
	(0.039)	(0.092)	(1.168)	(0.045)	(0.041)	(0.934)
Q^{end}	0.038	−0.163**	4.108**	−0.052	−0.031	−0.385
	(0.054)	(0.065)	(1.652)	(0.044)	(0.030)	(0.957)
JP	−1.711***	−0.036	−38.587***	−2.542***	−1.426***	−26.010***
	(0.049)	(0.042)	(1.001)	(0.087)	(0.108)	(4.571)
$Q^{end} : JP$	0.116	0.047	1.837	0.175**	−0.104	5.963*
	(0.078)	(0.059)	(2.058)	(0.077)	(0.081)	(3.445)
Controls						
$Q^{end} : Y^{end}$	−0.535***	−0.170	−7.932**	−0.532***	0.013	−12.506***
	(0.082)	(0.221)	(3.631)	(0.082)	(0.093)	(2.134)
$Q^{end} : Y^{end} : JP$	0.330***	0.039	6.144***	0.181	−0.059	5.922
	(0.091)	(0.102)	(2.220)	(0.149)	(0.266)	(7.238)
Observations	140	140	140	218	218	218
Adj. R^2	0.883	0.002	0.863	0.927	0.586	0.366

Table I3: All models are OLS with Newey-West standard errors. Dependent variable is the amount of US dollars borrowed in swaps, in repo, and as a share as defined in eq. (9). Models (1)-(3) use UK G-SIBs as a control, (4)-(6) use US G-SIBs. Q_t^{end} (Y_t^{end}) is a dummy indicating a quarter-end (year-end) and JP_i is unity for Japanese banks and 0 for UK (US) banks. Frequency is monthly; sample runs from September 2012 to September 2021. FX swaps are volumes outstanding of dollars borrowed in CLS; repo volumes are amounts outstanding of USD borrowing in US MMFs.

Appendix J



(a) Net USD FX swap borrowing, Δ bn USD

(b) USD repo borrowing, Δ bn USD

Fig. J1: The plot displays the coefficient β_1 from the following regression: $Y_t = \alpha + \beta_1 \cdot Q^{end} + \beta_2 \cdot Y^{end} + \epsilon_t$, where Q^{end} and Y^{end} quarter- and year-end time dummies respectively. In the l.h.s. Y_t is the net borrowing of USD in FX swaps; in the r.h.s. panel, it is the gross borrowing of USD from US MMFs. We consider tenors up to one-week. The regression is run for banks of each nationality (including non-G-SIBs). Green (red) coloring indicates a statistically significant positive (negative) β_1 coefficient at the 1% significance level whereas gray coloring indicates no significance. The dots refer to the point estimates of the β_1; line bars add and subtract three times its standard deviation. Regulatory quarter-ends serve as the basis of the event study from December 2015 to September 2021.

Appendix K

We test our evidence through a difference-in-differences regression whereby we check whether Eurozone bank borrowing increases for those currencies that involve the US dollar, and compare our results to US and UK G-SIBs. We thus run the following model:

$$SwapBorrowing_t = \delta_0 + \delta_1 \cdot USD_t + \delta_2 \cdot Q_t^{end} + \delta_3 \cdot Q_t^{end} \cdot USD_t + \delta \cdot \mathrm{X} + u_t \tag{K.1}$$

where $SwapBorrowing_t$ is the outstanding amount of FX swap borrowing undertaken on day t, Q^{end} (Y^{end}) is the day of the quarter-end, USD is a dummy variable indicating whether that FX swap borrowing was for US dollars or for foreign currency, and $\delta \cdot \mathrm{X} = \delta_4 \cdot Q^{end} \cdot Y^{end} + \delta_5 \cdot Q^{end} \cdot Y^{end}$ is a set of control variables. Results are displayed in Table (K1).

	Volume					
	Eurozone G-SIBs		US G-SIBs		UK G-SIBs	
	Bill.	Log	Bill.	Log	Bill.	Log
USD	-20.72^{**}	-0.12^{**}	206.50^{***}	0.63^{***}	-45.88^{**}	-0.24^{*}
	(8.88)	(0.05)	(32.08)	(0.09)	(22.40)	(0.14)
Q^{end}	-0.06	0.005	29.07^{***}	0.12^{***}	2.82	0.02
	(4.86)	(0.03)	(9.80)	(0.04)	(6.64)	(0.04)
$USD : Q^{end}$	33.83^{***}	0.19^{***}	-50.02^{***}	-0.17^{***}	3.28	0.02
	(8.04)	(0.05)	(18.35)	(0.05)	(8.68)	(0.06)
Constant	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	144	144	144	144	144	144
Adj. R^2	0.330	0.353	0.646	0.687	0.230	0.228

Table K1: Volumes are summed across all currency pairs and are USD-denominated. $SwapBorrowing_t$ is the log outstanding amount of FX swap borrowing undertaken by G-SIBs on day t, Q^{end} is the day of the quarter-end, USD is a dummy variable indicating whether that FX swap borrowing was for US dollars or for foreign currency. Controls are for the year-end, i.e. $\mathrm{X} = \delta_4 \cdot Q^{end} \cdot Y^{end} + \delta_5 \cdot Q^{end} \cdot Y^{end}$.

Across all currency pairs, Eurozone G-SIB dollar borrowing increases by 17%, whereas non-dollar borrowing at the quarter-end increases by an insignificant 0.5%. US G-SIBs increase their dollar lending to accommodate this demand. Crucially, however, these dynamics are not visible for UK G-SIBs, which do not report their balance sheets as a quarter-end snapshot; the coefficient is economically and statistically insignificant. Dollar (non-dollar) volumes increase by 3.8% (2.1%).

Appendix L

We aim to show that European banks active in both Euro and US dollar repo markets scale back their activity in the latter, but not the former. In order to do so, we calculate the outstanding amount of repo borrowing for each bank in the Eurozone and abroad in the US (i.e. for EUR and USD respectively). Given the reporting frequency of US MMF data, we are limited to monthly observations. We run a difference-in-differences model as follows:

$$
\begin{aligned}
EZRepoBorrowing_{i,t} = {} & \beta_1 \cdot USD_{i,t} + \beta_2 \cdot Q_t^{end} + \beta_3 \cdot USD_{i,t} \cdot Q_t^{end} + \beta_4 \cdot Y_t^{end} \\
& + \beta_5 \cdot Q_t^{end} \cdot Y_t^{end} \cdot EZ_i + \alpha_i + u_{i,t}
\end{aligned}
\tag{L.1}
$$

where $EZRepoBorrowing_{i,t}$ is the outstanding amount of repo borrowing[39] of Eurozone bank i at time t, USD is a dummy variable indicating whether that volume borrowed US dollars (euros), Q^{end} (Y^{end}) is a dummy variable denoting whether time t represents a quarter-end (year-end), and α_i are bank-specific fixed effects. β_3 is thus the difference-in-differences estimator. We run the regression model on both absolute and logarithmic volumes (the latter giving us a percentage reaction). The first two specifications of Table (L1) consider all banks in our sample; as a further robustness check, the second two specifications solely consider those banks for which we have data in both US and European markets. Finally, to give us a total magnitude, specifications (5) and (6) run OLS regressions on all volumes combined.

All specifications show strong statistical and economical significance for the difference-in-differences estimator. Column (2) tells us that the average treatment effect per bank is 41%. Column (5) shows that the quarter-end results in an US$ 61 billion drop for all banks combined in our sample; this corresponds well with the visualization in Figure (5). Thus, our bank-specific data tells us that those European banks which are window-dressing in US MMFs do so less, if any, in Europe.

[39] We exclude reverse repos (which do not have a regulatory cost); thus we are only considering cash borrowing in money markets.

	Eurozone G-SIB repo borrowing					
	bn USD	log	bn USD	log	bn USD	log
USD	13.941*	0.552*	14.897*	0.587*	−62.978***	−0.285***
	(7.037)	(0.312)	(7.035)	(0.291)	(9.907)	(0.048)
Q^{end}	0.213	0.064	−0.078	−0.020	6.082	0.022
	(0.158)	(0.040)	(0.296)	(0.046)	(13.414)	(0.065)
$Q^{end} : USD$	−7.066***	−0.346***	−6.874**	−0.259**	−61.151***	−0.353***
	(2.460)	(0.106)	(2.524)	(0.092)	(18.971)	(0.092)
Controls						
$Q^{end} : Y^{end}$	−1.829***	−0.274***	−2.504**	−0.311*	−64.020***	−0.257***
	(0.493)	(0.075)	(0.859)	(0.158)	(22.880)	(0.111)
$Q^{end} : Y^{end} : USD$	−0.594	0.130	0.060	0.176	44.337	0.142
	(1.942)	(0.095)	(1.829)	(0.169)	(32.357)	(0.156)
Constant	No	No	No	No	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	No	No
Frequency	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly
Standard errors	Clustered	Clustered	Clustered	Clustered	Newey-West	Newey-West
Obs.	4,486	4,486	1,654	1,654	216	216
Adjusted R^2	0.609	0.667	0.448	0.509	0.369	0.393

Table L1: Specifications (1)-(2) are panel regressions with bank fixed effects, considering all banks in the sample; (3)-(4) only consider those banks which appear in both BrokerTec and US MMF data. (5)-(6) are ordinary least squares (OLS) regressions summing up all banks' volume. $EZRepoBorrowing_{i,t}$ is the outstanding amount of repo borrowing of Eurozone bank i at time t, USD is a dummy variable indicating whether that volume borrowed US dollars (euros), Q^{end} (Y^{end}) is a dummy variable denoting whether time t represents a quarter-end (year-end).

Appendix M

	Swap Share (%)				
	EZ	CH	JP	UK	US
β_0	41.59***	84.28***	33.36***	68.94***	70.41***
	(2.20)	(2.04)	(4.42)	(2.81)	(0.99)
Q^{end}	12.05***	9.01***	5.95***	4.59***	−0.46
	(1.71)	(1.53)	(1.26)	(1.03)	(0.72)
$Q^{end} : Y^{end}$	−5.64	−3.94	−2.95	−8.99***	−11.52***
	(3.48)	(2.43)	(2.65)	(2.90)	(2.09)
Obs.	82	82	82	82	82
Adj. R^2	0.23	0.22	0.01	0.06	0.32

Table M1: All models are OLS with Newey-West standard errors. Dependent variable is the share of total USD borrowing through FX swaps, as defined in eq. (9). Q_t^{end} (Y_t^{end}) is a dummy indicating a quarter-end (year-end). Frequency is monthly; the sample starts in the 2015 year-end and ends in September 2021. FX swaps volumes are amounts outstanding of dollars borrowed in CLS and repo volumes are amounts outstanding of USD borrowing from US MMFs.

Appendix N

We estimate a bank-level difference-in-differences model comparing the outstanding amount of secured vs. unsecured US dollar borrowing by the various G-SIB banking groups at the quarter-end. $Funding^{\$}$ is the outstanding amount of US dollars borrowed from US MMFs. *Secured* is a dummy variable with value 1 if the quantities borrowed were through repo instruments, and with value 0 if they were instead borrowed through unsecured means.

$$Funding^{\$}_{i,t} = \beta_1 \cdot Q^{end}_t + \beta_2 \cdot Secured_{i,t} + \beta_3 \cdot Q^{end}_t \cdot Secured_{i,t} + \beta_4 \cdot Q^{end}_t \cdot Y^{end}_t + \beta_5 \cdot Q^{end}_t \cdot Y^{end}_t \cdot Secured_t + \alpha_i + u_{i,t} \tag{N.1}$$

where α_i are G-SIB fixed effects. Table (N1) shows results. We estimate bank-level regressions on European, UK, and US banks separately.

	Wholesale USD borrowing					
	EZ/CH G-SIBs		UK GS-SIBs		US GS-SIBs	
	bn USD	log	bn USD	log	bn USD	log
	(1)	(2)	(3)	(4)	(5)	(6)
Secured	16.18**	0.72	8.42	−0.62	10.18*	0.86
	(6.71)	(0.41)	(7.86)	(1.32)	(4.33)	(0.88)
Q^{end}	−1.00	−0.04	−0.22	−0.14	−0.13	0.03
	(0.71)	(0.03)	(0.48)	(0.13)	(0.32)	(0.10)
$Secured : Q^{end}$	−8.68***	−0.34**	−1.46	0.01	−0.28	0.01
	(2.08)	(0.11)	(1.62)	(0.09)	(0.41)	(0.09)
Controls						
$Q^{end} : Y^{end}$	−0.88	−0.08	0.25	0.08	0.85	0.13
	(0.64)	(0.10)	(0.40)	(0.14)	(0.45)	(0.12)
$Secured : Q^{end} : Y^{end}$	−2.21	0.02	−5.21*	−0.40**	−1.11	−0.14
	(2.80)	(0.08)	(1.72)	(0.06)	(0.95)	(0.15)
Fixed effects	G-SIB	G-SIB	G-SIB	G-SIB	G-SIB	G-SIB
Clustering	G-SIB	G-SIB	G-SIB	G-SIB	G-SIB	G-SIB
Observations	1,246	1,246	364	364	1,422	1,422
Adj. R^2	0.388	0.410	0.584	0.482	0.531	0.490

Table N1: Models are panel regressions with G-SIB-level fixed and clustering. Dependent variable is billions of wholesale USD funding, measured in absolute values and in logs. *Secured* is a dummy variable denoting whether such funding was secured or unsecured, Q^{end} (Y^{end}) denotes whether the position was outstanding during a quarter-end (year-end).

For Eurozone and Swiss G-SIBs, secured funding (i.e. repo) significantly diminishes at the quarter-end by almost 9 billion USD per G-SIB, a 29% drop. No significant dynamics are observed for unsecured funding. Furthermore, unaffected UK and US banks similarly do not window-dress either their secured or unsecured funding, in line with our prior. This demonstrates that repo-FX swap substitution is a shift from regulatory-costly secured funding to synthetic dollar funding.

Appendix O

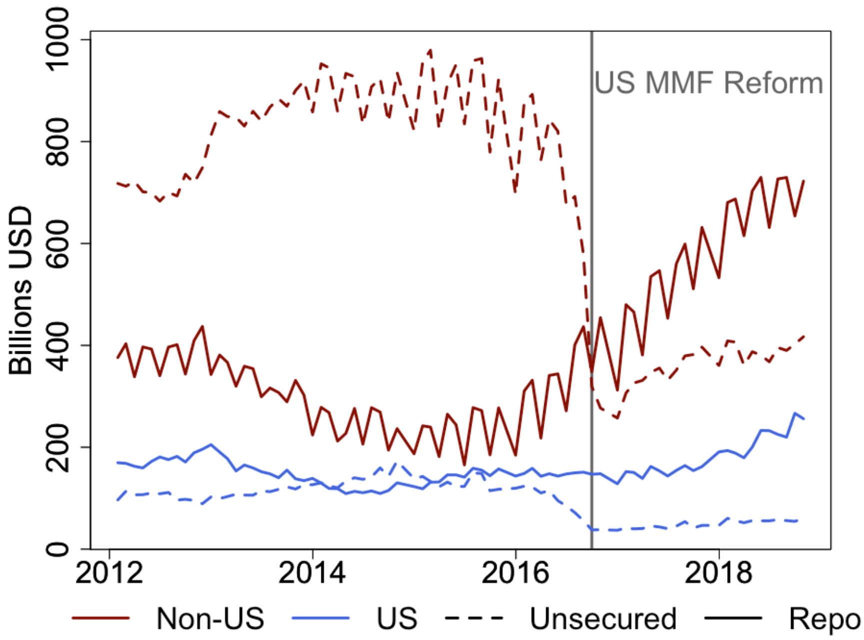


Fig. O1: Plot of US and non-US secured (repo) and unsecured funding volumes around the 2016 US MMF reform.

Appendix P

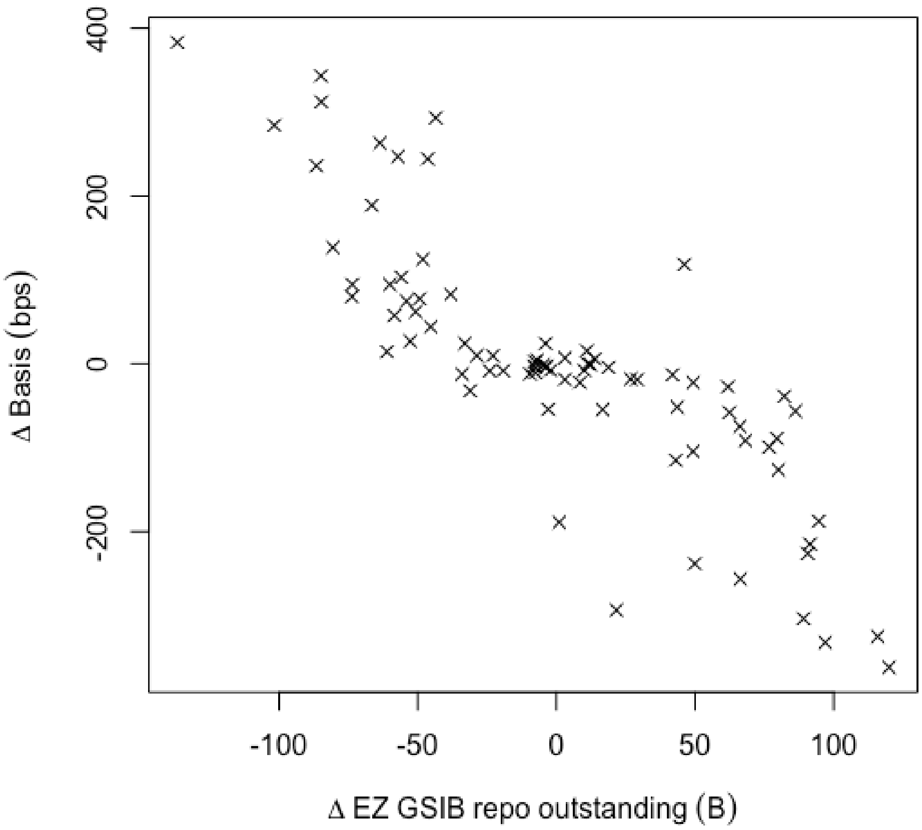


Fig. P1: Scatterplot of changes in the cross-currency basis (USDJPY 1W, in basis points) versus differenced outstanding Eurozone G-SIB repo positions in US money markets. Observations are month-end and span from 2015 to 2022.

Appendix Q

Our conceptual framework predicts that the cross-currency basis will increase the more it is costly to source dollars from US MMFs. As discussed earlier, one of the factors making US wholesale funding *relatively* prohibitive is the extent to which collateral is required for such operations. We now put the prediction to the test. We consider Eurozone and Swiss G-SIBs' wholesale funding and derive the share of their secured wholesale funding, $\Delta^{Secured}$, as follows:

$$\Delta_t^{Secured} := \frac{\sum_{j=1}^{J}\left(\mathcal{O}_{j,t}^{Secured}\right)}{\sum_{j=1}^{J}\left(\mathcal{O}_{j,t}^{Secured} + \mathcal{O}_{j,t}^{Unsecured}\right)} \cdot 100 \tag{Q.1}$$

where $\mathcal{O}$ denotes an outstanding quantity of US dollar borrowing from US MMFs. We consider repo as secured, and commercial paper (CP), certificates of deposit (CD) as unsecured.[40] We then plot, on a monthly basis, the share of costly secured borrowing vs. the cross-currency basis (in this case, EURUSD 1W). Given that these banks substitute out of secured borrowing at the quarter-end, we use the previous month's value for the share of secured borrowing, such that we are considering a correlation of χ_t with $\Delta_{t-1}^{Secured}$. Figure (Q1) shows that a strong correlation exists between the reliance on secured borrowing, and the cross-currency basis.

The plot shows that both during and outside the quarter-end reporting period, the share of secured borrowing heavily coincides with spikes in the cross-currency basis. Interestingly, there remains a strong correlation between the basis and the share of secured borrowing even outside of the quarter-end. This suggests that non-regulatory relative costs also play a role; a plausible explanation is that difficulties in sourcing the requisite collateral increase banks' synthetic reservation price.

[40] These G-SIBs' wholesale funding consists of the following sources: repo (67.8%), CP (13.1%), CD (12.6%), and "Other" (6.5%). The results we show below are robust when including other sources of financing in the denominator).

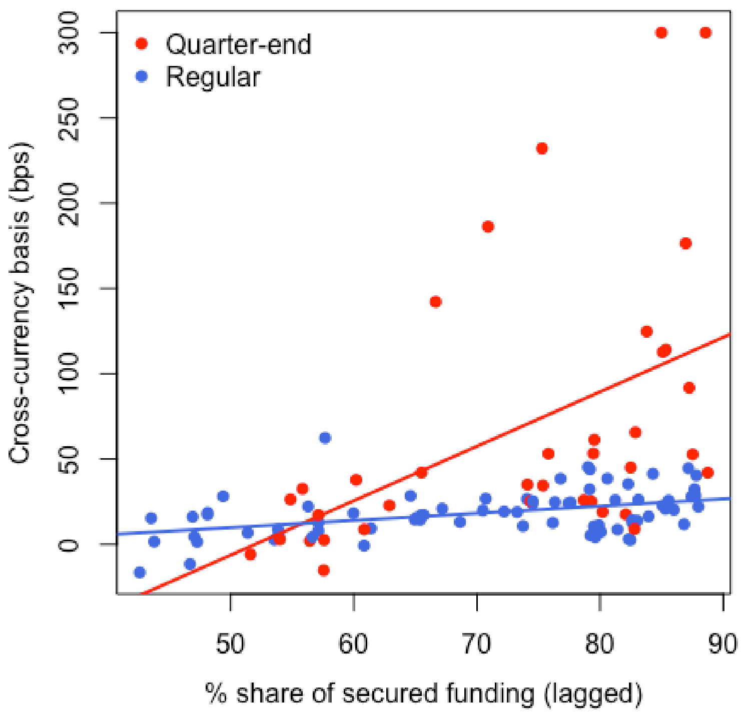


Fig. Q1: Scatterplot of the share of secured borrowing by European G-SIBs compared with the cross-currency basis. The secured borrowing share is a lagged value from the previous month. Basis is EURUSD 1W, with values capped at 300 basis points for visualization. Red (blue) dots denote values during (outside of) the quarter-end. Sample ranges from November 2011 to September 2021.

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